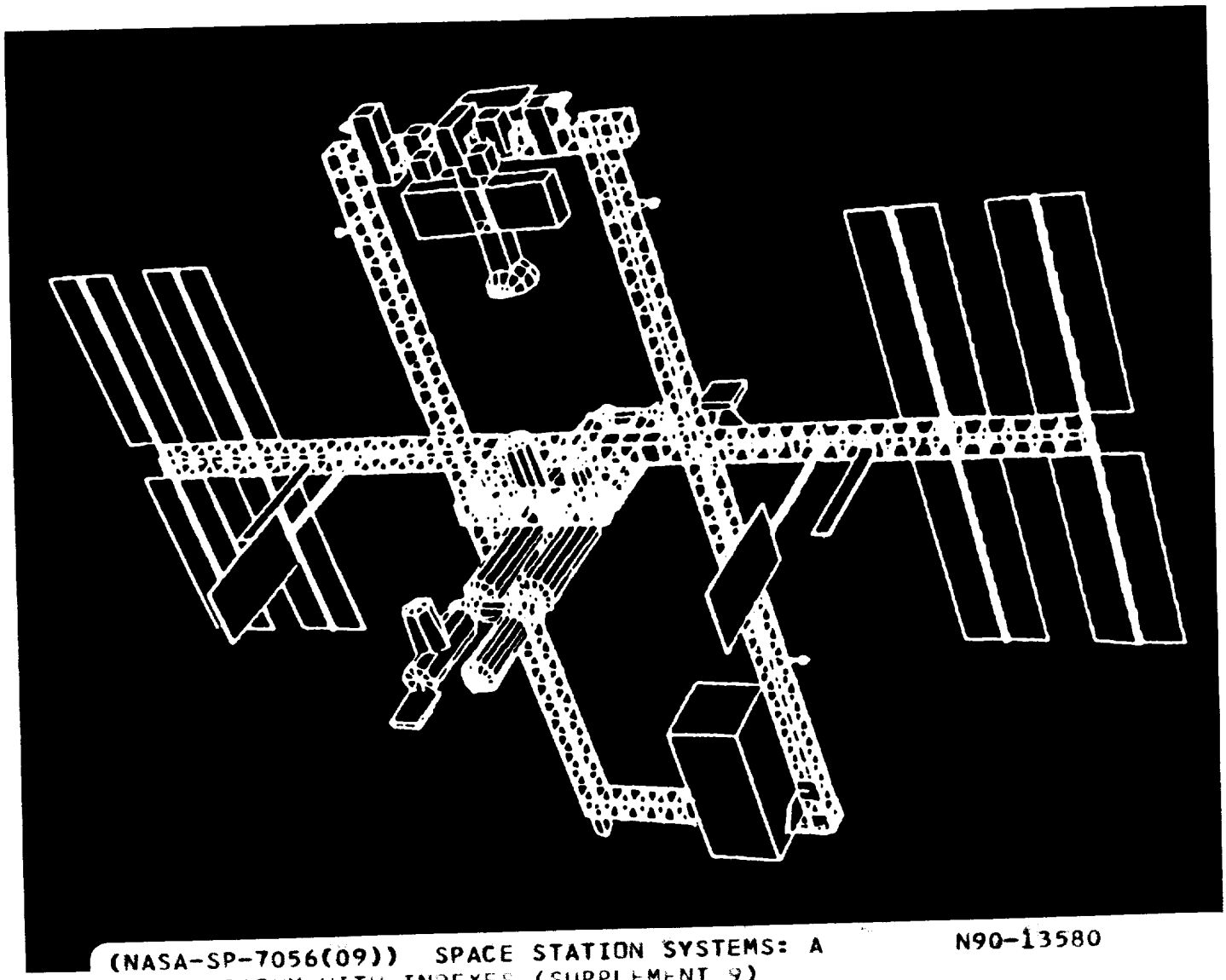
NASA

Space Station Systems

A Bibliography
with Indexes

NASA SP-7056 (09)
November 1989



(NASA-SP-7056(09)) SPACE STATION SYSTEMS: A BIBLIOGRAPHY WITH INDEXES (SUPPLEMENT 9) (NASA) 325 p

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NASA SP-7056 (09)

SPACE STATION SYSTEMS

A BIBLIOGRAPHY WITH INDEXES

Supplement 9

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and
Edited by
Space Station Office
NASA Langley Research Center
Hampton, Virginia

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system between January 1 and June 30, 1989 in

- *Scientific and Technical Aerospace Reports (STAR)*
- *International Aerospace Abstracts (IAA).*

National Aeronautics and Space Administration
Office of Management
Scientific and Technical Information Division
Washington, DC 1989

NOTE TO AUTHORS OF PROSPECTIVE ENTRIES:

The compilation of this bibliography results from a complete search of the *STAR* and *IAA* files. Many times a report or article is not identified because either the title, abstract, or key words did not contain appropriate words for the search. A number of words are used, but to best insure that your work is included in the bibliography, use the words *Space Station Systems* somewhere in your title or abstract, or include them as a key word.

This supplement is available from the National Technical Information Service (NTIS), Springfield , Virginia 22161 at the price code A15.

INTRODUCTION

This bibliography is designed to be helpful to the researchers, designers, and managers engaged in the design and development of technology, configurations, and procedures that enhance efficiencies of current and future versions of a Space Station.

This literature survey lists 1313 reports, articles and other documents announced between January 1, 1989 and June 30, 1989 in *Scientific and Technical Aerospace Reports (STAR)*, and *International Aerospace Abstracts (IAA)*.

The coverage includes documents that define major systems and subsystems, servicing and support requirements, procedures and operations, and missions for the current and future Space Station. In addition, analytical and experimental techniques and mathematical models required to investigate the different systems/subsystems and conduct trade studies of different configurations, designs, and scenarios are included. A general category completes the list of subjects addressed by this document.

The selected items are grouped into categories as listed in the Table of Contents with notes regarding the scope of each category. These categories were especially selected for this publication and differ from those normally found in *STAR* and *IAA*.

Each entry consists of a standard bibliographic citation accompanied by an abstract, where available, and appears with the original accession numbers from the respective announcement journals.

Under each of the categories, the entries are presented in one of two groups that appear in the following order:

(1) *IAA* entries identified by accession number series A89-10,000 in ascending accession number order;

(2) *STAR* entries identified by accession number series N89-10,000 in ascending accession number order.

After the abstract section there are seven indexes—subject, personal author, corporate source, foreign technology, contract number, report number, and accession number.

A companion continuing bibliography, *"Technology for Large Space Structures,"* is available as NASA SP-7046.

George F. Lawrence, *Space Station Office*
John J. Ferrainolo, *Technical Library Branch*

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Category 03 Structural Concepts Includes analyses and descriptions of different Space Station structural concepts, arrangements, testing, methods of construction and/or manufacturing and specific rotary joints, structural nodes, and columns.	12
Category 04 Thermal Control Includes descriptions of analytical techniques, passive and active thermal control techniques, external and internal thermal experiments and analyses and trade studies of thermal requirements.	34
Category 05 Environmental Control and Life Support Systems Includes description of analytical techniques and models, trade studies of technologies, subsystems, support strategies, and experiments for internal and external environmental control and protection, life support systems, human factors, life sciences and safety.	40
Category 06 Dynamics and Controls Includes descriptions of analytical techniques and computer codes, trade studies, requirements and decriptions of orbit maintenance systems, rigid and flexible body attitude sensing systems and controls such as momentum wheels and/or propulsive schemes.	50
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Category 14 Growth 132
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Catefory 20 Life Sciences/Human Factors/Safety 181
Includes studies, models, planning, analyses and simulations for biological and medical laboratories, habitability issues for the performance and well-being of the crew, and crew rescue.

Category 21 General 187
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Subject Index A-1
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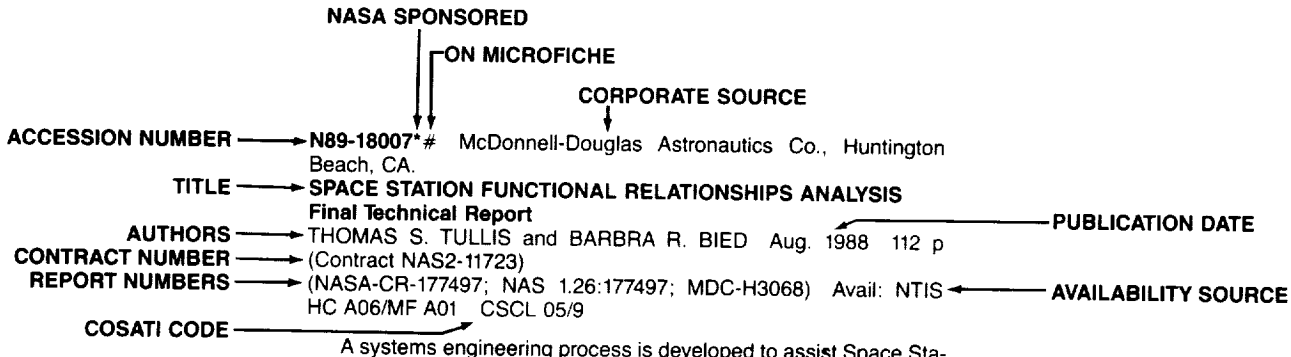
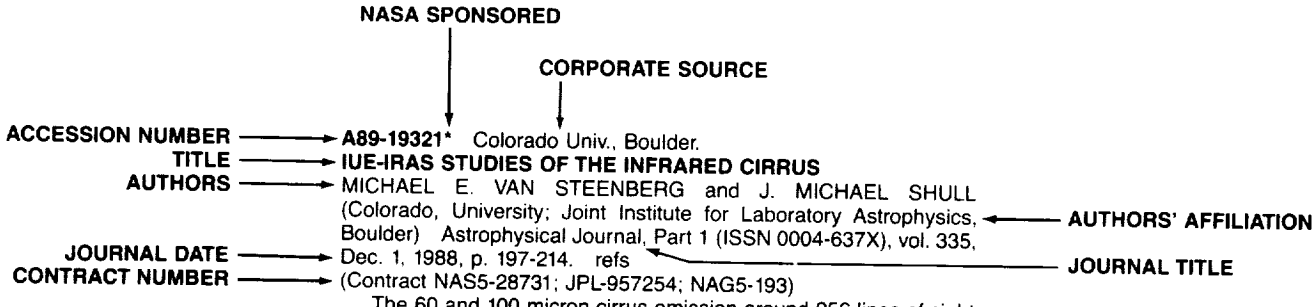
TYPICAL REPORT CITATION AND ABSTRACT



A systems engineering process is developed to assist Space Station designers to understand the underlying operational system of the facility so that it can be physically arranged and configured to support crew productivity. The study analyzes the operational system proposed for the Space Station in terms of mission functions, crew activities, and functional relationships in order to develop a quantitative model for evaluation of interior layouts, configuration, and traffic analysis for any Station configuration. Development of the model involved identification of crew functions, required support equipment, criteria of assessing functional relationships, and tools for analyzing functional relationship matrices, as well as analyses of crew transition frequency, sequential dependencies, support equipment requirements, potential for noise interference, need for privacy, and overall compatability of functions. The model can be used for analyzing crew functions for the Initial Operating Capability of the Station and for detecting relationships among these functions. Note: This process (FRA) was used during Phase B design studies to test optional layouts of the Space Station habitat module. The process is now being automated as a computer model for use in layout testing of the Space Station laboratory modules during Phase C. Author

TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT



The 60 and 100 micron cirrus emission around 256 lines of sight in the IRAS all-sky survey was measured, and the flux averages were used to study the distribution, variations, and correlations of the IRAS infrared cirrus fluxes with various interstellar parameters. It was found that the 60 and 100 micron fluxes correlate with the depletion of Si and show a trend with the depletion of Fe for 51 lines of sight toward the Galactic halo. No correlation was found with the abundances of Si, Mn, Fe, S, or Zn or with abundance ratios for the full sample of 256 stars. An abundance ratio of about 3 x 10 to the 7th by number relative to H was derived from 60 and 100 micron flux ratios and the H column along the line of sight; this ratio appears to decrease by a factor of 10 into the halo. I.S.

SPACE STATION SYSTEMS

A Bibliography (Suppl. 9)

NOVEMBER 1989

01

SYSTEMS

Includes system requirements for proposed missions, mission models, overall conceptual configuration and arrangement studies; systems analyses for future required technology; and identification and description of technology developments and experiments for the elements of a complete Space Station system.

A89-10486
SPACE-FLIGHT PERSPECTIVES - GUIDING PRINCIPLES FOR TECHNOLOGICAL RESEARCH AND DEVELOPMENT [PERSPEKTIVEN DER RAUMFAHRT - LEITKONZEPTE FUER TECHNOLOGISCHE FORSCHUNG UND ENTWICKLUNG]
D. E. KOELLE (Messerschmitt-Boelkow-Blohm GmbH, Ottobrunn, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 11-14. In German.
(DGLR PAPER 87-071)

The fundamental goals laid out in the FRG Planning Framework for High Technology and Space Flight (OHR) are examined and illustrated with block diagrams and drawings of proposed spacecraft. The need for long-term planning and coordination on a national level is stressed, and particular attention is given to orbital systems and infrastructure (participation in the International Space Station, polar and GEO platforms, and lunar stations) and space transportation systems (heavy cargo vehicle, hypersonic transport, manned launch vehicle, OTV concepts, and lunar lander). T.K.

A89-10650
STRUCTURE DESIGN CONSIDERATIONS OF ENGINEERING TEST SATELITE VI AS LARGE GEOSTATIONARY SATELLITE BUS
HIDEHIKO MITSUMA (National Space Development Agency of Japan, Tokyo) IN: International Pacific Air and Space Technology Conference, Melbourne, Australia, Nov. 13-17, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 281-285.
(SAE PAPER 872431)

The paper considers aspects of the structural design of the Japanese Engineering Test Satellite VI as a large geostationary satellite bus for applications satellites in the 1990s. Particular attention is given to the characteristics of the antenna tower structure, the solar array hold-down points, and the apogee-kick-engine support structure. In addition, the test plan of the structural research model is presented. B.J.

A89-11346
FLUID-SCIENCE INVESTIGATIONS IN MICROGRAVITY
J. P. B. VREEBURG (Nationaal Lucht- en Ruimtevaartlaboratorium, Amsterdam, Netherlands) IN: Microgravity research - Status and prospects; Proceedings of the SRON Symposium, Utrecht, Netherlands, Apr. 2, 3, 1987. Utrecht, Space Research Organization Netherlands, 1987, p. 59-75. refs

Four classes of fluid-science investigations in microgravity are discussed: molecular physics, thermodynamic and transport coefficients, classical heat and mass transfer, and fluid mechanics. The realization of experiments in space is addressed with attention given to a fluid-science laboratory concept for Columbus. Means of reducing costs and strengthening the authority of investigators are suggested. K.K.

A89-12247* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
ATOMIC OXYGEN MODELING IN THE UPPER THERMOSPHERE
A. E. HEDIN (NASA, Goddard Space Flight Center, Greenbelt, MD) Planetary and Space Science (ISSN 0032-0633), vol. 36, Sept. 1988, p. 907-920. refs

Empirical models of atomic oxygen in the earth's thermosphere are discussed, and calibration problems in satellite drag and in situ mass spectrometer measurements are reviewed. Models based on drag data and mass spectrometer data are found to agree on average to within 15 percent, suggesting that the absolute values are reasonably well known in the upper thermosphere. Comparison of different models with various data sources show residuals of at least 15 percent which are the results of unmodeled magnetic storm, EUV, and geographical variations and smaller scale variations caused by gravity waves. R.R.

A89-12626
ASTRODYNAMICS 1987; PROCEEDINGS OF THE AAS/AIAA ASTRODYNAMICS CONFERENCE, KALISPELL, MT, AUG. 10-13, 1987. PARTS 1 & 2
JOHN K. SOLDNER, ED. (Science Applications International Corp., Schaumburg, IL), ARUN K. MISRA, ED. (McGill University, Montreal, Canada), ROBERT E. LINDBERG, ED. (Orbital Sciences Corp., Fairfax, VA), and WALTON WILLIAMSON, ED. (Sandia National Laboratories, Albuquerque, NM) Conference sponsored by AAS and AIAA. San Diego, CA, Univelt, Inc., 1988, p. Pt. 1, 870 p.; pt. 2, 919 p. For individual items see A89-12627 to A89-12715.

Papers on astrodynamics are presented, concerning space transportation, LEO orbit determination, optimal control, gravity assist missions, precise orbit determination, multibody dynamics and tethered satellite, the NASA Mars exploration program, semianalytic satellite theory. NORAD programs, structural identification and control, planetary mission and payload analysis, celestial mechanics, satellite debris and orbit decay, the dynamics and control of rotating structures, outer planetary exploration, and attitude dynamics are also discussed. Other topics include satellite constellations and the GPS system, inner planetary exploration, attitude control, orbit analysis and synthesis, future mission studies, tracking and orbit determination, orbital dynamics, geosynchronous and high altitude orbit analysis, satellite drag coefficients, and rendezvous, intercept, and evasive maneuvers. R.B.

A89-14751
MECHANICS AND SCIENTIFIC-TECHNOLOGICAL PROGRESS. VOLUME 1 - GENERAL AND APPLIED MECHANICS [MEKHANIKA I NAUCHNO-TEKHNICHESKII PROGRESS. VOLUME 1 - OBSHCHAIA I PRIKLADNAIA MEKHANIKA]
A. IU. ISHLINSKII, ED., N. N. KRASOVSKII, ED., V. V. RUMIANTSEV, ED., and V. N. RUBANOVSKII, ED. Moscow, Izdatel'stvo Nauka, 1987, 296 p. In Russian. For individual items see A89-14752 to A89-14763.

The papers presented in this volume provide an overview of recent research related to a variety of problems in theoretical and applied mechanics. Topics discussed include asymptotic methods in nonlinear mechanics, absolute stability of nonlinear periodic systems, computer algebra methods in mechanics problems, and inverse problems in the dynamics of controlled systems. The discussion also covers game theory problems concerned with the estimation of motion parameters in the presence of nonmodeled accelerations, dynamics of tethered space systems, and trajectory control problems. V.L.

A89-15645
DESIGN OF SPACECRAFT VERIFIED BY TEST IN A MODULAR FORM
EBERHARD ERBEN (MBB/ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) and C. STAVRINIDIS (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IN: International Modal Analysis Conference, 6th, Kissimmee, FL, Feb. 1-4, 1988, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. 1721-1729. Sponsorship: European Space Research and Technology Centre. refs
(Contract ESTEC-6891/85/NL/PH(SC))

A modular verification procedure is described whereby the identification and qualification testing of a complete mechanical structure is performed on the modular segment level rather than on the integrated assembly level. The reliability of the modular verification procedure depends to a great extent on the quality of the analytical models describing the modular segments and forming the basis for the synthesis of the integrated assembly model. Synthesis methods for different data sets are examined. V.L.

A89-16541#
SPACE STATION - DESIGNING FOR OPERATIONS AND SUPPORT
JAMES T. KAIDY, WILLIAM G. BASTEDO, JR. (Booz, Allen and Hamilton, Inc., Bethesda, MD), and THOMAS M. CRABB Aerospace America (ISSN 0740-722X), vol. 26, Nov. 1988, p. 18-20.

Design priorities resulting in such characteristics as modularity, orbital servicing and maintenance, standardized elements, and streamlined procedures, are being brought to bear on the definition of the NASA Space Station. Attention is presently given to the consequence of these design concerns for the multivariable optimization problem posed by the Space Station's on-orbit assembly sequence; the Station's hardware design requirements are driven by the assembly sequence defined. O.C.

A89-17627#
CONCEPTUAL DESIGN OF PLATFORMS IN 1990'S
T. TAKAGI, N. TSUYA, and H. OBARA (Mitsubishi Electric Corp., Space Systems Dept., Kamakura, Japan) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 12 p.
(IAF PAPER 88-0004)

The technologies for the space platforms and the space servicers of the Space Infrastructure are reviewed. Technologies for rendezvous and docking, in-orbit services, and autonomous operation and control are discussed. The development of an Advanced Technology Coordinating Platform (ATCP) and an Orbital Servicing Vehicle (OSV) is proposed to demonstrate these technologies. The mission requirements, system requirements, and system concept of the ATCP and OSV are presented. R.B.

A89-17658*# NASA Space Station Program Office, Reston, VA.
SPACE STATION DESIGN INTEGRATION
RICHARD F. CARLISLE (NASA, Space Station Freedom Program Office, Reston, VA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 7 p.
(IAF PAPER 88-063)

This paper discusses the top Program level design integration process which involves the integration of a US Space Station manned base that consists of both US and international Elements. It explains the form and function of the Program Requirements Review (PRR), which certifies that the program is ready for preliminary design, the Program Design Review (PDR), which certifies the program is ready to start the detail design, and the Critical Design Review (CDR), which certifies that the program is completing a design that meets the Program objectives. The paper also discusses experience, status to date, and plans for continued system integration through manufacturing, testing and final verification of the Space Station system performance. Author

A89-17669*# NASA Space Station Program Office, Reston, VA.
INTERNATIONAL INTERFACE DESIGN FOR SPACE STATION FREEDOM - CHALLENGES AND SOLUTIONS
RICHARD E. MAYO (NASA, Reston, VA), GORDON R. BOLTON, and DANIELE LAURINI (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 13 p.
(IAF PAPER 88-085)

The definition of interfaces for the International Space Station is discussed, with a focus on negotiations between NASA and ESA. The program organization and division of responsibilities for the Space Station are outlined; the basic features of physical and functional interfaces are described; and particular attention is given to the interface management and documentation procedures, architectural control elements, interface implementation and verification, and examples of Columbus interface solutions (including mechanical, ECLSS, thermal-control, electrical, data-management, standardized user, and software interfaces). Diagrams, drawings, graphs, and tables listing interface types are provided. T.K.

A89-19321* Colorado Univ., Boulder.
IUE-IRAS STUDIES OF THE INFRARED CIRRUS
MICHAEL E. VAN STEENBERG and J. MICHAEL SHULL (Colorado, University; Joint Institute for Laboratory Astrophysics, Boulder) Astrophysical Journal, Part 1 (ISSN 0004-637X), vol. 335, Dec. 1, 1988, p. 197-214. refs
(Contract NAS5-28731; JPL-957254; NAG5-193)

The 60 and 100 micron cirrus emission around 256 lines of sight in the IRAS all-sky survey was measured, and the flux averages were used to study the distribution, variations, and correlations of the IRAS infrared cirrus fluxes with various interstellar parameters. It was found that the 60 and 100 micron fluxes correlate with the depletion of Si and show a trend with the depletion of Fe for 51 lines of sight toward the Galactic halo. No correlation was found with the abundances of Si, Mn, Fe, S, or Zn or with abundance ratios for the full sample of 256 stars. An abundance ratio of about 3 x 10 to the 7th by number relative to H was derived from 60 and 100 micron flux ratios and the H column along the line of sight; this ratio appears to decrease by a factor of 10 into the halo. I.S.

A89-25161*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
CONSERVATION OF DESIGN KNOWLEDGE
CECILIA SIVARD, MONTE ZWEBEN (NASA, Ames Research Center, Moffett Field, CA), DAVID CANNON, FRED LAKIN, LARRY LEIFER (Stanford University, Palo Alto, CA) et al. AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(Contract NCC2-342)
(AIAA PAPER 89-0186)

This paper presents an approach for acquiring knowledge about a design during the design process. The objective is to increase the efficiency of the lifecycle management of a space-borne system by providing operational models of the system's structure and behavior, as well as the design rationale, to human and automated operators. A design knowledge acquisition system is under development that compares how two alternative design versions meet the system requirements as a means for automatically capturing rationale for design changes. Author

A89-25198# Houston Univ., TX.
PROPOSED THIN FILM GROWTH IN SPACE ULTRA-VACUUM - INTEGRATED SEMICONDUCTOR-SUPERCONDUCTOR MATERIALS
A. IGNATIEV, A. BENSAOULA, and J. HUGHES (Houston, University, TX) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 4 p. Research supported by NASA and DARPA. refs
(AIAA PAPER 89-0231)

The epitaxial growth of high quality compound semiconductors has been previously proposed for the ultra-vacuum environment made possible in low earth orbit space through the development of a wake shield. The expectation of compound semiconductor thin films with low defect densities grown in this environment, and recent indications that atomic oxygen can be effective in the growth of thin film high temperature superconductors with superior characteristics, call for the integration of thin film semiconductor and thin film high temperature superconductor materials in the unique vacuum environment of space. The merger of the two technologies is critical for the effective application of the new superconductor materials which are expected to be first seen in the thin film arena. Author

A89-25212*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
EOS MISSION DESIGN UTILIZING THE SPACE STATION PLATFORMS
CHRISTOPHER J. SCOLESE (NASA, Goddard Space Flight Center, Greenbelt, MD) and LAWRENCE C. SCHOLZ (General Electric Co., Astro Space Div., Princeton, NJ) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 29 p. refs
(AIAA PAPER 89-0252)

NASA is formulating a program that will encompass many scientific disciplines and involve a large share of the international scientific community in the study of planet earth. The mission is planned for the 1990s and will involve at least four spacecraft: two provided by the NASA and one each provided by European Space Agency (ESA) and Japan. The NASA platforms will utilize elements of the Space Station Freedom program to provide the basic spacecraft engineering subsystems. These subsystems are intended to serve as the basis for future earth orbiting United States spacecraft. Author

A89-25296#
DISTURBANCE ON GSTAR SATELLITES DUE TO THRUSTER PLUME IMPINGEMENT ON SOLAR ARRAY
S. A. PARVEZ (GTE Spacenet, McLean, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p.
(AIAA PAPER 89-0351)

Data available from an operational GSTAR satellite are used to compute the actual disturbance torques experienced during north/south maneuvers due to plume impingement on solar arrays as a function of the array position. It is shown that roll and yaw disturbance torques go through a complete cycle as the array position during north/south burns goes through one complete rotation, while the pitch disturbance torque goes through two cycles. The maximum roll and yaw disturbance torque has an approximate magnitude of 0.10 in-lbf, while the maximum pitch disturbance torque has a magnitude of 0.04 in-lbf. The analysis shows that the solar arrays may be bent in the direction of the sun. K.K.

A89-25537*# Colorado State Univ., Fort Collins.
PLASMA CONTACTING - AN ENABLING TECHNOLOGY
JOHN D. WILLIAMS and PAUL J. WILBUR (Colorado State University, Fort Collins) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(Contract NAG3-776)
(AIAA PAPER 89-0677)

An experimental study of plasma contacting with an emphasis on the electron collection mode of this process is described. Results illustrating variations in plasma property profiles and potential differences that develop at hollow cathode plasma contactors are presented. A model of the electron collection plasma contacting process that is consistent with experimentally measured results is reviewed. The shortcomings of laboratory results as direct predictors of contactor performance in space and their usefulness in validating numerical models of the contacting process, that can be used to predict such performance, are discussed. Author

A89-25551#
THE EVOLUTION OF EXTERNAL TANK APPLICATIONS
J. ALEX GIMARC (USAF, Space Studies Institute, Colorado Springs, CO) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 6 p. refs
(AIAA PAPER 89-0727)

The External Tank of the Space Shuttle offers unique opportunities for orbital applications. Early interest was oriented toward the on-orbit storage and use of the tank as various habitats. Work during the early 1980s detailed on-orbit applications as tethered bodies, life sciences experiments, cargo carriers, materials resources in space, and the basis of a wide variety of manned platforms. Current interest is primarily in the areas of manned or man-tended platforms and the construction of a large telescope for gamma-ray observation. Author

A89-25552#
THE OUTPOST CONCEPT - A MARKET DRIVEN COMMERCIAL PLATFORM IN ORBIT
THOMAS C. TAYLOR, CHARLES W. COOK, and WILLIAM A. GOOD (Global Outpost, Inc., Alexandria, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0729)

The OUTPOST concept, a platform in LEO derived from the external tank of the Space Shuttle, is examined. The OUTPOST platform is expected to be used for orbital exposure testing, small science and research experiments, and technology testing and development. The use of the external tank and experimental accomodations on the platform are considered and the platform configuration and mission profile are illustrated. Plans for the marketing and commercial use of the platform, and other government contracts involving use of the Space Shuttle external tanks are discussed. R.B.

A89-26386#
ECONOMICS AND RATIONALE FOR MATERIAL PROCESSING USING FREE-FLYING PLATFORMS
RICHARD BOUDREAULT (Canadian Astronautics, Ltd., Ottawa, Canada) IN: Commercial opportunities in space; Symposium, Taipei, Republic of China, Apr. 19-24, 1987, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 161-176. Research supported by Canadian Astronautics, Ltd. refs

The use of space platforms for the production of materials in a microgravity production is reviewed. The platforms considered include the Space Shuttle, the Space Station, and existing unmanned free-flying platforms. The economics of each type of platform is summarized and the minimum breakeven price for products is discussed in terms of production volume, initial investment, and space platforms. This cost is compared to the price of the different materials. It is concluded that the free-flying platform provides the most economically viable microgravity environment. R.B.

A89-27910
A BASELINE DESIGN FOR THE SPACE STATION HABITAT
RICHARD L. OLSON, BRAND N. GRIFFIN, and JAMES S. HAWKINS (Boeing Aerospace, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 16 p.
(SAE PAPER 881119)

A baseline design has been selected for the Space Station Habitat (HAB) element. The HAB element is designed to provide an environment that maximizes safety and human productivity. This paper outlines some of the current design features, including the common core elements and the man-systems hardware. Author

A89-28232* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
ALTERNATE TRANSPORTATION SYSTEM
TONY ZERTUCHE (Barrios Technology, Inc., Houston, TX) and JAMES MCKINNIE (NASA, Johnson Space Center, Houston, TX) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 20 p. refs
(SAE PAPER 881496)

Three missions have been identified by NASA for a Space Shuttle-supplementing Alternate Transportation System (ATS) encompassing combinations of booster vehicles, crew modules, and service modules: (1) to achieve manned access to orbit for Space Station crew rotation every 90 days, (2) the lofting of a logistics module resupplying the Space Station every 180 days, and (3) the simultaneous launch of both crews and logistics to the Space Station. A reentry glider is considered, in conjunction with the Space Shuttle's unmanned cargo version and the Apollo manned capsule, as an important ATS element. The Titan IV/NUS is used as a booster. O.C.

A89-29405
MULTI-ROLE CAPSULE SYSTEM DESCRIPTION
C. M. HEMPSELL and RUSSELL J. HANNIGAN (British Aerospace, PLC, Space and Communications Div., Stevenage, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 42, Feb. 1989, p. 67-81.

The Multi-Role Capsule (MRC) is a concept for a recoverable capsule capable of working in a manned and unmanned mode. It has two module configuration: a descent module to contain the crew and major systems, and a jettisonable service module with equipment that is only required in orbit. It would be launched on Ariane 4, and be capable of carrying up to six men or 1500 kg of payload. Author

A89-32162
OPTIMIZATION OF THE TRAJECTORIES AND PARAMETERS OF INTERORBITAL TRANSPORT VEHICLES WITH LOW-THRUST ENGINES [OPTIMIZATSIIA TRAEKTORII I PARAMETROV MEZHORBITAL'NYKH TRANSPORTNYKH APPARATOV S DVIGATELIAMI MALOI TIAGI]
S. A. ISHKOV and V. V. SALMIN Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 27, Jan.-Feb. 1989, p. 42-53. In Russian. refs

The problem of choosing optimal parameters and control programs for interorbital transport vehicles with low-thrust engines is examined. The spacecraft dynamics with respect to the center of mass and additional fuel expenditures for the purpose of control are taken into account in solving the dynamic and parameteric optimization problems. An iterative scheme is proposed for the joint optimization of the parameters and motion control laws. B.J.

A89-32163
MATHEMATICAL SUBSTANTIATION OF A THEORY OF ORBITAL CORRECTION USING A SOLAR SAIL [MATEMATICHESKOE OBOSNOVANIE TEORII ORBITAL'NOI KORREKTSII, VYPOLNIAEMOI S POMOSHCH'IU SOLNECHNOGO PARUSA]
E. N. POLIAKHOVA and A. S. SHMYROV Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 27, Jan.-Feb. 1989, p. 54-63. In Russian. refs

The paper examines the two-dimensional problem of the optimal correction of the geocentric elliptical orbit of a spacecraft using a solar sail. A combination of the averaging and small-parameter methods is used to obtain an approximately optimal solution. The problem is examined for arbitrary initial conditions in the sense of the orientation of the apsidal lines and the dimensions of the elliptical orbit with fixed constraints on the solar-sail thrust force. B.J.

N89-10922*# Alabama Univ., Huntsville. Center for Microgravity and Materials Research.
PROCESS MODELLING FOR SPACE STATION EXPERIMENTS Annual Report No. 1, 1 Oct. 1987 - 30 Sep. 1988
FRANZ ROSENBERGER and J. IWAN D. ALEXANDER 24 Oct. 1988 51 p
(Contract NAG8-684)
(NASA-CR-183274; NAS 1.26:183274) Avail: NTIS HC A04/MF A01 CSCL 22A

The work performed during the first year 1 Oct. 1987 to 30 Sept. 1988 involved analyses of crystal growth from the melt and from solution. The particular melt growth technique under investigation is directional solidification by the Bridgman-Stockbarger method. Two types of solution growth systems are also being studied. One involves growth from solution in a closed container, the other concerns growth of protein crystals by the hanging drop method. Following discussions with Dr. R. J. Naumann of the Low Gravity Science Division at MSFC it was decided to tackle the analysis of crystal growth from the melt earlier than originally proposed. Rapid progress was made in this area. Work is on schedule and full calculations were underway for some time. Progress was also made in the formulation of the two solution growth models. Author

N89-11765*# National Aeronautics and Space Administration, Washington, DC.
SPACE RESEARCH AND TECHNOLOGY BASE OVERVIEW
LANA M. COUCH *In its* Technology for Future NASA Missions: Civil Space Technology Initiative (CSTI) and Pathfinder p 107-130 Sep. 1988
Avail: NTIS HC A23/MF A01 CSCL 22/1

Information in viewgraph form is given on aerothermodynamics, space energy conversion, spacecraft propulsion, spacecraft construction materials, spacecraft communications, spacecraft control, human factors engineering, and systems analysis. R.J.F.

N89-11766*# National Aeronautics and Space Administration, Washington, DC.
IN-SPACE TECHNOLOGY EXPERIMENTS PROGRAM: INSTEP
JUDITH H. AMBRUS *In its* Technology for Future NASA Missions: Civil Space Technology Initiative (CSTI) and Pathfinder p 131-142 Sep. 1988
Avail: NTIS HC A23/MF A01 CSCL 22/1

Information is given in viewgraph form on space research and technology strategy, space shuttle experiments, experiments' planning, industry/university experiments, plasma arc welding in space, and international in-space experiments. R.J.F.

N89-11777*# National Aeronautics and Space Administration, Washington, DC.
FLIGHT PROJECTS OVERVIEW
JACK LEVINE *In its* Technology for Future NASA Missions: Civil Space Technology Initiative (CSTI) and Pathfinder p 357-377 Sep. 1988
Avail: NTIS HC A23/MF A01 CSCL 22/1

Information is given in viewgraph form on the activities of the Flight Projects Division of NASA's Office of Aeronautics and Space Technology. Information is given on space research and technology strategy, current space flight experiments, the Long Duration Exposure Facility, the Orbiter Experiment Program, the Lidar In-Space Technology Experiment, the Ion Auxiliary Propulsion System, the Arcjet Flight Experiment, the Telerobotic Intelligent Interface Flight Experiment, the Cryogenic Fluid Management Flight Experiment, the Industry/University In-Space Flight Experiments, and the Aeroassist Flight Experiment. R.J.F.

N89-12752*# National Aeronautics and Space Administration, Washington, DC.
MICROGRAVITY SCIENCE AND APPLICATIONS PROGRAM TASKS, 1987 REVISION
Aug. 1988 239 p
(NASA-TM-4068; NAS 1.15:4068) Avail: NTIS HC A11/MF A01 CSCL 12/1

A compilation is presented of the active research tasks as of the end of the FY87 of the Microgravity Science and Applications Program, NASA-Office of Space Science and Applications, involving several NASA centers and other organizations. An overview is provided of the program scope for managers and scientists in industry, university, and government communities. An introductory description is provided of the program along with the strategy and overall goal, identification of the organizational structures and people involved, and a description of each task. A list of recent publications is also provided. The tasks are grouped into six major categories: Electronic Materials; Solidification of Metals, Alloys, and Composites; Fluid Dynamics and Transport Phenomena; Biotechnology; Glasses and Ceramics; and Combustion. Other categories include Experimental Technology, General Studies and Surveys; Foreign Government Affiliations; Industrial Affiliations; and Physics and Chemistry Experiments (PACE). The tasks are divided into ground based and flight experiments. Author

N89-13443*# Eagle Engineering, Inc., Houston, TX.
LLOFX EARTH ORBIT TO LUNAR ORBIT DELTA V ESTIMATION PROGRAM USER AND TECHNICAL DOCUMENTATION
Apr. 1988 44 p
(Contract NAS9-17878)
(NASA-CR-172091; NAS 1.26:172091; EEI-88-212) Avail: NTIS HC A03/MF A01 CSCL 22/3

The LLOFX computer program calculates in-plane trajectories from an Earth-orbiting space station to Lunar orbit in such a way that the journey requires only two delta V burns (one to leave Earth circular orbit and one to circularize into Lunar orbit). The program requires the user to supply the Space Station altitude and Lunar orbit altitude (in km above the surface), and the desired time of flight for the transfer (in hours). It then determines and displays the trans-Lunar injection (TLI) delta V required to achieve the transfer, the Lunar orbit insertion (LOI) delta V required to circularize the orbit around the Moon, the actual time of flight, and whether the transfer orbit is elliptical or hyperbolic. Return information is also displayed. Finally, a plot of the transfer orbit is displayed. Author

N89-13459* National Aeronautics and Space Administration, Washington, DC.
SPACE STATION SYSTEMS: A BIBLIOGRAPHY WITH INDEXES (SUPPLEMENT 6)
Jul. 1988 294 p
(NASA-SP-7056(06); NAS 1.21:7056(06)) Avail: NTIS HC A13 CSCL 22/2

This bibliography lists 1,133 reports, articles, and other documents introduced into the NASA scientific and technical information system between July 1, 1987 and December 31, 1987. Its purpose is to provide helpful information to the researcher, manager, and designer in technology development and mission design according to system, interactive analysis and design, structural and thermal analysis and design, structural concepts and control systems, electronics, advanced materials, assembly concepts, propulsion, and solar power satellite systems. The coverage includes documents that define major systems and subsystems, servicing and support requirements, procedures and operations, and missions for the current and future Space Station. Author

N89-13481* National Aeronautics and Space Administration, Washington, DC.
TECHNOLOGY FOR LARGE SPACE SYSTEMS: A BIBLIOGRAPHY WITH INDEXES (SUPPLEMENT 19)
Nov. 1988 145 p
(NASA-SP-7046(19); NAS 1.21:7046(19)) Avail: NTIS HC A07 CSCL 22/2

This bibliography lists 526 reports, articles, and other documents introduced into the NASA scientific and technical information system between January 1, 1988 and June 30, 1988. Its purpose is to provide helpful information to the researcher, manager, and designer in technology development and mission design according to system, interactive analysis and design, structural and thermal analysis and design, structural concepts and control systems, electronics, advanced materials, assembly concepts, propulsion, and solar power satellite systems. Author

N89-13678# Pacific Northwest Labs., Richland, WA.
REDUCED GRAVITY BOILING AND CONDENSING EXPERIMENTS SIMULATED WITH THE COBRA/TRAC COMPUTER CODE
J. M. CUTA and W. J. KROTIUK Feb. 1988 27 p Presented at the 1st AIAA, ASME, SIAM and APS National Fluid Dynamics Congress, Cincinnati, Ohio, 24 Jul. 1988
(Contract DE-AC06-76RL-01830)
(DE88-016311; PNL-SA-15368; CONF-880716-8) Avail: NTIS HC A03/MF A01

It is being recognized that there does not currently exist an adequate understanding of flow and heat transfer behavior in reduced- and zero-gravity. There is not a sufficient experimental fluid-thermal data base to develop design correlations for two-phase pressure losses, heat transfer coefficients, and critical heat flux limits in systems proposed for advanced power sources, propulsion, and other thermal management systems in space. Pacific Northwest Laboratory (PNL), is the lead laboratory for thermal hydraulics in the Department of Energy's Multimegawatt Space Power Program, and has the responsibility of developing microgravity thermal-hydraulic analysis capabilities for application to space nuclear power systems. In support of this program, PNL has performed a series of reduced-gravity two-phase flow experiments in the NASA KC-135 aircraft. The objective of the experiment was to supply basic thermal-hydraulic information that could be used in development of analytical design tools. DOE

N89-14999*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
PLANETARY IMPACT EXPERIMENTATION
MARK J. CINTALA, PETER H. SCHULTZ (Brown Univ., Providence, RI.), and FRIEDRICH HOERZ *In its* Experiments in Planetary and Related Sciences and the Space Station 16 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 03/2

An understanding of impact processes in low- and microgravity environments would be advanced significantly by the construction and use of an impact facility on the Space Station. It is proposed that initial studies begin as soon as possible in ground-based impact laboratories, on the NASA KC-135 Reduced-Gravity Aircraft, and in existing drop towers. The resulting experience and information base could then be applied toward an experiment package designed for use on Shuttle orbiters to support pilot studies in orbital environments. These experiments, as well as the first efforts made on the IOC Space Station, should involve the impact of various free-floating targets; such studies would yield a substantial scientific return while providing valuable experience and engineering information for use in refining the design of the dedicated Space Station Impact Facility. The dedicated facility should be designed to support impact experimentation, including but not limited to cratering, asteroid and ring-particle dynamics, and accretional processes. Author

N89-15002*# Lawrence Livermore National Lab., CA.
EXPERIMENTAL COSMOCHEMISTRY IN THE SPACE STATION
AL DUBA *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 4 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 03/2

The purpose of two workshops was to identify and discuss experiments in cosmochemistry that cannot be conducted under the conditions available in terrestrial laboratories, but may be carried out successfully in the proposed Space Station. The scientific discussions focused on two general areas of research: chemical and physical processes in the earliest history of the general areas of research, and general principles of magmatic process applicable both to planetary formation and evolution, as well as present-day magmatic activity in and on terrestrial planets. Author

N89-15020*# Iowa State Univ. of Science and Technology, Ames. Dept. of Aerospace Engineering.
SEDIMENT-TRANSPORT EXPERIMENTS IN ZERO-GRAVITY
JAMES D. IVERSEN and RONALD GREELEY (Arizona State Univ., Tempe.) *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 3 p Nov. 1987 Previously announced as N86-27153
Avail: NTIS HC A09/MF A01 CSCL 22/1

One of the important parameters in the analysis of sediment entrainment and transport is gravitational attraction. The availability of a laboratory in earth orbit would afford an opportunity to conduct experiments in zero and variable gravity environments. Elimination of gravitational attraction as a factor in such experiments would enable other critical parameters (such as particle cohesion and aerodynamic forces) to be evaluated much more accurately. A Carousel Wind Tunnel (CWT) is proposed for use in conducting experiments concerning sediment particle entrainment and transport in a space station. In order to test the concept of this wind tunnel design a one third scale model CWT was constructed and calibrated. Experiments were conducted in the prototype to determine the feasibility of studying various aeolian processes and the results were compared with various numerical analysis. Several types of experiments appear to be feasible utilizing the proposed apparatus. Author

N89-15024*# Rice Univ., Houston, TX. Dept. of Space Physics and Astronomy.
A MAGNETOSPHERIC SIMULATION AT THE SPACE STATION Abstract Only
R. E. LOPEZ, JOHN W. FREEMAN, and F. C. MICHEL *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 1 p Nov. 1987 Previously announced as N86-27155
Avail: NTIS HC A09/MF A01 CSCL 03/2

It is proposed that a strong magnet (terrella) be flown at or near the Space Station to create an artificial magnetosphere in a laboratory setting. The relative flow of the ionosphere past the terrella will constitute a plasma wind that will interact with the magnetic field of the terrella to produce a localized magnetosphere. This object could then be extensively studied using diagnostic probes attached to the Space Station or with free flyers. The space and storage requirements would be minimal, since the experiment would be conducted outside the Space Station. The total equipment would consist of several terrella (with varying surface conductivities), approximately 3 small magnetometer/plasma diagnostic packages, and several gas canisters for upstream seeding. Power requirements would be approximately 60 watts. Several track mounted tethers, each approximately or 200 m long in length, with track parallel to the orbital motion and 100 m long, are also needed. Astronaut time needed would be minimal in the tethered configuration (approximately 4 man hours/week). A free flying configuration, while not needing the tether track, would require much more human interaction. Author

N89-15026*# Arizona State Univ., Tempe. Dept. of Geology.
CAUTIONARY TALES FOR REDUCED-GRAVITY PARTICLE RESEARCH
JOHN R. MARSHALL, RONALD GREELEY, and D. W. TUCKER *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 3 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 22/1

Failure of experiments conducted on the KC-135 aircraft in zero gravity are discussed. Tests that were a total failure are reported. Why the failure occurred and the sort of questions that potential researchers should ask in order to avoid the appearance of abstracts such as this are discussed. Many types of aggregation studies were proposed for the Space Station, and it is hoped that the following synopsis of events will add a touch of reality to experimentation proposed for this zero-gravity environment. Author

N89-15030*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
NUCLEATION AND PARTICLE COAGULATION EXPERIMENTS IN MICROGRAVITY
J. NUTH *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 4 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 22/1

Measurements of the conditions under which carbon, aluminum oxide, and silicon carbide smokes condense and of the morphology and crystal structure of the resulting grains are essential if the nature of the materials ejected into the interstellar medium and the nature of the grains which eventually became part of the proto solar nebular are to be understood. Little information is currently available on the vapor-solid phase transitions of refractory metals and solids. What little experimental data do exist are, however, not in agreement with currently accepted models of the nucleation process for more volatile materials. The major obstacle to performing such experiments in earth-based laboratories is the susceptibility of these systems to convection. Evaporation of refractory materials into a low-pressure environment with a carefully controlled temperature gradient will produce refractory smokes when the critical supersaturation of the system is exceeded. Measurement of the point at which nucleation occurs, via light scattering or extinction, can not only yield nucleation data but also, information on the chemical composition and crystal structure of the condensate. Experimental requirements are presented. Author

N89-15032*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
LOW-GRAVITY FACILITIES FOR SPACE STATION PLANETOLOGY EXPERIMENTS
PAUL A. PENZO *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 2 p Nov. 1987 Previously announced as N86-27160
Avail: NTIS HC A09/MF A01 CSCL 22/1

For experimentation, space offers an environment which is unobtainable on earth. One characteristic is a gravity force less than 1 g, where g is the mean earth gravity acceleration of 9.8 m/sq s. The production of uniform gravity levels above zero g in space is discussed in relationship to experimental needs. For planetology experiments, providing gravity in space will make it possible to more nearly simulate conditions on natural bodies. The g-level is but one parameter involved in the design of a specific experiment. Other requirements may be: g-level range; g-level tolerance value; Coriolis tolerance value; volume requirement g-level duration; power and materials for the experiment; and automated or man-tended operations. These requirements, and certainly others, will dictate the type of facility which should be considered. The use of the Space Station of the Tethered Satellite System configurations is discussed. B.G.

N89-15045*# Arizona Univ., Tucson. Dept. of Planetary Sciences.
CONTAINERLESS HIGH-PRESSURE PETROLOGY EXPERIMENTS IN THE MICROGRAVITY ENVIRONMENT OF THE SPACE STATION Abstract Only
W. V. BOYNTON, DRAKE, HILDEBRAND, JONES, LEWIS, TREIMAN, and WARK *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 2 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 22/1

The genesis of igneous rocks on terrestrial planets can only be understood through experiments at pressures corresponding to those in planetary mantles (10 to 50 kbar). Such experiments typically require a piston-cylinder apparatus, and an apparatus that has the advantage of controllable pressure and temperature, adequate sample volume, rapid sample quench, and minimal danger of catastrophic failure. It is proposed to perform high-pressure and high-temperature piston-cylinder experiments aboard the Space Station. The microgravity environment in the Space Station will minimize settling due to density contrasts and may, thus, allow

experiments of moderate duration to be performed without a platinoid capsule and without the sample having to touch the container walls. The ideal pressure medium would have the same temperatures. It is emphasized, however, that this proposed experimental capability requires technological advances and innovations not currently available. Author

N89-15604*# Carleton Univ., Ottawa (Ontario). School of Computer Science.
A DYNAMIC CASE-BASED PLANNING SYSTEM FOR SPACE STATION APPLICATION
F. OPPACHER and D. DEUGO *In* NASA, Marshall Space Flight Center, Fourth Conference on Artificial Intelligence for Space Applications p 431-439 Oct. 1988 Sponsored in part by the Canadian Space Station Program Office of the National Research Council
Avail: NTIS HC A21/MF A01 CSCL 05/1

We are currently investigating the use of a case-based reasoning approach to develop a dynamic planning system. The dynamic planning system (DPS) is designed to perform resource management, i.e., to efficiently schedule tasks both with and without failed components. This approach deviates from related work on scheduling and on planning in AI in several aspects. In particular, an attempt is made to equip the planner with an ability to cope with a changing environment by dynamic replanning, to handle resource constraints and feedback, and to achieve some robustness and autonomy through plan learning by dynamic memory techniques. We briefly describe the proposed architecture of DPS and its four major components: the PLANNER, the plan EXECUTOR, the dynamic REPLANNER, and the plan EVALUATOR. The planner, which is implemented in Smalltalk, is being evaluated for use in connection with the Space Station Mobile Service System (MSS). Author

N89-15798*# Physical Sciences, Inc., Andover, MA. Applied Sciences.
REQUIREMENTS FOR PARTICULATE MONITORING SYSTEM FOR SPACE STATION
BYRON DAVID GREEN *In* NASA, Marshall Space Flight Center, Space Station Induced Monitoring p 47-49 Nov. 1988
Avail: NTIS HC A05/MF A01 CSCL 22/2

We recommend that a stereo camera system be utilized as a diagnostic for the particulate environment surrounding the Space Station. This system should have sufficient sensitivity to identify contaminated periods, to isolate the effects of sources and activities and to determine optical clearing times. A reasonable compromise between sensitivity and other operational constraints is recommended. Sensitivity comparable to the film camera systems should suffice, but long periods of unattended operation and remotely controlled exposure sequences are essential requirements. Author

N89-17403*# Universities Space Research Association, Houston, TX. Dept. of Mechanical Engineering and Aerospace Sciences.
THE SPACE STATION INTEGRATED REFUSE MANAGEMENT SYSTEM
LOREN A. ANDERSON May 1988 280 p
(Contract NGT-21-002-080; NGT-80001)
(NASA-CR-184722; NAS 1.26:184722) Avail: NTIS HC A13/MF A01 CSCL 06/11

The design and development of an Integrated Refuse Management System for the proposed International Space Station was performed. The primary goal was to make use of any existing potential energy or material properties that refuse may possess. The secondary goal was based on the complete removal or disposal of those products that could not, in any way, benefit astronauts' needs aboard the Space Station. The design of a continuous living and experimental habitat in space has spawned the need for a highly efficient and effective refuse management system capable of managing nearly forty-thousand pounds of refuse annually. To satisfy this need, the following four integrable systems were researched and developed: collection and transfer; recycle and reuse; advance disposal; and propulsion assist in disposal. The design of a Space Station subsystem capable of collecting and transporting refuse from its generation site to its disposal and/or recycling site was accomplished. Several methods of recycling or reusing refuse in the space environment were researched. The optimal solution was determined to be the method of pyrolysis. The objective of removing refuse from the Space Station environment, subsequent to recycling, was fulfilled with the design of a jettison vehicle. A number of jettison vehicle launch scenarios were analyzed. Selection of a proper disposal site and the development of a system to propel the vehicle to that site were completed. Reentry into the earth atmosphere for the purpose of refuse incineration was determined to be the most attractive solution. Author

N89-18007*# McDonnell-Douglas Astronautics Co., Huntington Beach, CA.
SPACE STATION FUNCTIONAL RELATIONSHIPS ANALYSIS Final Technical Report
THOMAS S. TULLIS and BARBRA R. BIED Aug. 1988 112 p
(Contract NAS2-11723)
(NASA-CR-177497; NAS 1.26:177497; MDC-H3068) Avail: NTIS HC A06/MF A01 CSCL 05/9

A systems engineering process is developed to assist Space Station designers to understand the underlying operational system of the facility so that it can be physically arranged and configured to support crew productivity. The study analyzes the operational system proposed for the Space Station in terms of mission functions, crew activities, and functional relationships in order to develop a quantitative model for evaluation of interior layouts, configuration, and traffic analysis for any Station configuration. Development of the model involved identification of crew functions, required support equipment, criteria of assessing functional relationships, and tools for analyzing functional relationship matrices, as well as analyses of crew transition frequency, sequential dependencies, support equipment requirements, potential for noise interference, need for privacy, and overall compatability of functions. The model can be used for analyzing crew functions for the Initial Operating Capability of the Station and for detecting relationships among these functions. Note: This process (FRA) was used during Phase B design studies to test optional layouts of the Space Station habitat module. The process is now being automated as a computer model for use in layout testing of the Space Station laboratory modules during Phase C. Author

N89-18522* National Aeronautics and Space Administration, Washington, DC.
SPACE STATION SYSTEMS: A BIBLIOGRAPHY WITH INDEXES (SUPPLEMENT 7)
Dec. 1988 289 p
(NASA-SP-7056(07); NAS 1.21:7056(07)) Avail: NTIS HC A13 CSCL 22/2

This bibliography lists 1,158 reports, articles, and other documents introduced into the NASA scientific and technical information system between January 1, 1988 and June 30, 1988. Its purpose is to provide helpful information to researchers, designers and managers engaged in Space Station technology development and mission design. Coverage includes documents that define major systems and subsystems related to structures and dynamic control, electronics and power supplies, propulsion, and payload integration. In addition, orbital construction methods, servicing and support requirements, procedures and operations, and missions for the current and future Space Station are included. Author

N89-19818*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
THE SCHEDULING TECHNIQUES OF ESP2
JOHN P. JAAP and ELIZABETH K. DAVIS *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 1-6 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 05/1

The Mission Analysis Division of the Systems Analysis and

Integration Laboratory at the Marshall Space Flight Center has developed a robust automatic scheduler which can produce detailed schedules for the multi-step activities required for payload operations on the Space Station. This scheduler, a part of the Expert Scheduling Program (ESP2), has five components: the bookkeeper, checker, loader, selector, and explainer. The bookkeeper maintains the usage profiles for nondepletable resources, consumables, equipment, crew, and the times of all the steps for the payload activities for several different schedules simultaneously. The checker searches the data maintained by the bookkeeper and finds times when the constraints of each step of an activity are satisfied. The loader is an expert system that uses the techniques of forward chaining, depth-first searching, and backtracking to manage the workings of the checker so that activities are placed in the schedule without violating constraints (such as crew, resources, and orbit opportunities). The checker searches the data maintained by the bookkeeper and finds times when the constraints of each step of an activity are satisfied. The loader is an expert system which uses the techniques of forward chaining, depth-first searching, and backtracking to manage the workings of the checker so that activities are placed in the schedule without violating the constraints. The selector has several methods of choosing the next activity for the loader to schedule. The explainer shows the user why an activity was or was not scheduled at a certain time; it offers a unique graphical explanation of how the expert system (the loader) works. Author

N89-20065*# Houston Univ., Clear Lake, TX. Div. of Life Sciences.
DEVELOPMENT OF AN ATMOSPHERIC MONITORING PLAN FOR SPACE STATION Final Report
DENNIS M. CASSERLY *In* NASA, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988, Volume 1 16 p Feb. 1989
Avail: NTIS HC A09/MF A01 CSCL 06/11

An environmental health monitoring plan for Space Station will ensure crew health during prolonged habitation. The Space Station, Freedom, will operate for extended periods, 90+ days, without resupply. A regenerative, closed loop life support system will be utilized in order to minimize resupply logistics and costs. Overboard disposal of wastes and venting of gases to space will be minimal. All waste material will be treated and recycled. The concentrated wastes will be stabilized and stored for ground disposal. The expected useful life of the station (decades) and the diversity of materials brought aboard for experimental or manufacturing purposes, increases the likelihood of cabin contamination. Processes by which cabin contamination can occur include: biological waste production, material off-gassing, process leakage, accidental containment breach, and accumulation due to poor removal efficiencies of the purification units. An industrial hygiene approach was taken to rationalize monitoring needs and to identify the substances likely to be present, the amount, and their hazard. Author

02

MODELS, ANALYTICAL DESIGN TECHNIQUES, AND ENVIRONMENTAL DATA

Includes descriptions of computerized interactive systems design and development techniques, computer codes, internal and external environmental models and data.

A89-10597
SPACE SIMULATION USING COMPUTER GENERATED IMAGERY
H. RAYMOND HALLETT and ROBERT E. JAHNKE (General Electric Co., Fairfield, CT) IN: Aerospace Behavioral Engineering Technology Conference, 6th, Long Beach, CA, Oct. 5-8, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 199-206.
(SAE PAPER 871907)

This paper discusses the role played by computer-generated imagery (CGI) in both the development of space systems and in the training of flight and ground crews. Attention is given to the COMPU-SCENE IV, the latest version of the COMPU-SCENE line of CGI capability which serves a wide variety of applications, including simulation of fighter/attack and space/planetary scenarios. Special attention is given to the particular simulation requirements for planetary space programs, such as the Mars Rover/Sample Return mission and comparable missions to the moon and other planets, and the simulation requirements for future space vehicles such as the Space Station. I.S.

A89-11684#
EQUATIONS OF MOTION OF SYSTEMS OF VARIABLE-MASS BODIES FOR SPACE STRUCTURE DEPLOYMENT SIMULATION
J. E. KEAT and J. D. TURNER (Cambridge Research Associates, MA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 549-562. refs
(Contract F04511-82-K-0038; F04611-86-C-0017)

The paper presents a formulation of the equations of motion of multibody systems with interbody mass flow. An example of a process which can be modeled by the formulation is the common one in which appendages are extended from the main body of a spacecraft. After the Introduction, the paper contains four main parts. The first presents basic material that is used subsequently. The second develops kinetics equations for a single body, such as a deploying boom, with time-varying mass. The third develops the multibody system dynamics equations. The fourth applies the formulation to a sample problem. Author

A89-11811
PETRI NETS - A TOOL FOR REPRESENTING CONCURRENT ACTIVITIES IN SPACE STATION APPLICATIONS
D. E. COOKE (Texas, University, El Paso) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 53-63. refs

With the complexities that are likely to be found in control processes aboard the Space Station, it is appropriate to identify a tool for the analysis of these structures at an early stage in the design. The interest in Petri nets for the representation of concurrent structures has grown considerably in the past few years. Introduced here is a robust notation for the machine representation of Petri nets. The notation has been used successfully in the control flow and data flow representations of systems. Author

A89-11819* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
A SYNCHRONIZED COMPUTATIONAL ARCHITECTURE FOR GENERALIZED BILATERAL CONTROL OF ROBOT ARMS
ANTAL K. BEJCZY and ZOLTAN SZAKALY (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 123-134.

This paper describes a computational architecture for an interconnected high speed distributed computing system for generalized bilateral control of robot arms. The key method of the architecture is the use of fully synchronized, interrupt driven software. Since an objective of the development is to utilize the processing resources efficiently, the synchronization is done in the hardware level to reduce system software overhead. The architecture also achieves a balaced load on the communication channel. The paper also describes some architectural relations to trading or sharing manual and automatic control. Author

A89-12180* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
THE INTEGRATED ANALYSIS CAPABILITY (IAC LEVEL 2.0)
HAROLD P. FRISCH (NASA, Goddard Space Flight Center, Greenbelt, MD) and ROBERT G. VOS (Boeing Aerospace Co., Seattle, WA) Engineering with Computers (ISSN 0177-0667), vol. 4, no. 1-2, 1988, p. 53-63. refs

The critical data management issues involved in the development of the integral analysis capability (IAC), Level 2, to support the design analysis and performance evaluation of large space structures, are examined. In particular, attention is given to the advantages and disadvantages of the formalized data base; merging of the matrix and relational data concepts; data types, query operators, and data handling; sequential versus direct-access files; local versus global data access; programming languages and host machines; and data flow techniques. The discussion also covers system architecture, recent system level enhancements, executive/user interface capabilities, and technology applications. V.L.

A89-15371
AN EFFICIENT SIMULATION ENVIRONMENT FOR SPACE POWER GENERATION SYSTEMS
RON HAMMOND (Boeing Computer Services Co., Seattle, WA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 537-542.

This paper presents two examples that demonstrate the use of the EASY dynamic analysis system (Harrison et al., 1987) for the analysis of space power generation systems. The first of these examples, a dc-to-dc voltage booster, is a system in which the major issue is the selection of component sizes and the assessment of dynamic response. The second is a voltage regulator, which provides an example of a system in which the major issue is the switching logic and control system design. It is shown that EASY can be simply and economically applied to detailed modeling, and that it offers many advantages over more conventional analyses and simulation tools. I.S.

A89-21178
HIERARCHICAL CONTROL OF INTELLIGENT MACHINES APPLIED TO SPACE STATION TELEROBOTS
J. S. ALBUS, R. LUMIA, and H. MCCAIN (NBS, Gaithersburg, MD) (California Institute of Technology, Workshop on Space Telerobotics, Pasadena, Jan. 1987) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 24, Sept. 1988, p. 535-541. refs

A hierarchical architecture is described which supports space station telerobots in a variety of modes. The system is divided into three hierarchies: task decomposition, world model, and sensory processing. Goals at each level of the task decomposition hierarchy are divided both spatially and temporarily into simpler commands for the next lower level. This decomposition is repeated until, at the lowest level, the drive signals to the robot actuators are generated. To accomplish its goals, task decomposition modules must often use information stored in the world model. The purpose of the sensory system is to update the world model as rapidly as possible to keep the model in registration with the physical world. The architecture of the entire control system hierarchy and how it can be applied to space telerobot applications are discussed. I.E.

A89-27845
FLUIDNET - A THERMAL AND HYDRAULIC SOFTWARE FOR THE PRELIMINARY SIZING OF FLUID LOOP SYSTEMS
S. ANDRE, J. N. CHELOTTI (Aerospatiale, Division Systemes Strategiques et Spatiaux, Cannes, France), J. F. GORY, and T. LAFON (CNES, Toulouse, France) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 12 p.
(SAE PAPER 881045)

The development and features of FLUIDNET, an interactive application computer program for preliminary sizing of fluid loop networks used in spacecraft active thermal control systems, are described. The multiple evolutions of the overall configuration of the Columbus and Hermes projects have made it necessary to quickly dimension new thermal management systems; this has instigated FLUIDNET's development. After a brief description of the program structure, component library, and solution method, an example of FLUIDNET's application to the thermal control subsystem design of the Hermes freon loop is given. S.A.V.

A89-27896* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
A SIMULATION SYSTEM FOR SPACE STATION EXTRAVEHICULAR ACTIVITY
JOSE A. MARMOLEJO (NASA, Johnson Space Center, Houston, TX) and CHARLES K. SHEPHERD, JR. SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 8 p.
(SAE PAPER 881104)

A simulation program has been developed which addresses the human factors required to provide a crewmember with productive information during Space Station EVA. The operation of the voice recognition and control system and helmet-mounted projection display in the Space Station Extravehicular Mobility Unit (EMU) is reviewed. The features of the simulation program are discussed, including logic flow, information types, and the man-machine interface techniques used in the simulation program, voice recognizer, and helmet-mounted display. R.B.

A89-28594* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CLOSED-FORM GRAMMIANS AND MODEL REDUCTION FOR FLEXIBLE SPACE STRUCTURES
TREVOR WILLIAMS (NASA, Langley Research Center, Hampton, VA) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1157, 1158. refs

Analytical expression are derived for the Grammians of a model in modal coordinates for the dynamics of a flexible space structure (FSS). These exact results provide insight into the dynamics of such systems and reduce the known approximate expressions in the case of lightly damped, widely separated modes. A novel algorithm is outlined that uses these to compute a dominant reduced-order model for such a system in an efficient manner. I.E.

A89-30817*# NASA Space Station Program Office, Reston, VA.
AN AUTOMATED, INTEGRATED APPROACH TO SPACE STATION STRUCTURAL MODELING
ALAN J. LINDENMOYER (NASA, Space Station Freedom Program Office, Reston, VA) and JOHN A. HABERMEYER (Grumman Corp., Space Station Program Support Div., Reston, VA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1591-1597.
(AIAA PAPER 89-1342)

NASA and its contractors have developed an integrated, interdisciplinary CAD/analysis system designated IDEAS(double asterisk)2 in order to conduct evaluations of alternative Space Station concepts' performance over the projected course of the Station's evolution in orbit. Attention is presently given to the requirements associated with automated FEM-building methods applicable to Space Station system-level structural dynamic analysis, and the ways in which IDEAS(double asterisk)2 addresses these requirements. Advantage is taken of the interactive capabilities of the SUPERTAB FEM preprocessor system for Space Station model manipulation and modification. O.C.

N89-10067*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

AUTOPLAN: A PC-BASED AUTOMATED MISSION PLANNING TOOL

FRANK C. PATERRA, MARC S. ALLEN (Computer Technology Associates, Inc., Newport News, Va.), and GEORGE F. LAWRENCE *In* NASA, Goddard Space Flight Center, Proceedings of 1987 Goddard Conference on Space Applications of Artificial Intelligence (AI) and Robotics 16 p 1987 Previously announced in IAA as A88-20486

Avail: NTIS HC A99/MF E03 CSCL 22A

A PC-based automated mission and resource planning tool, AUTOPLAN, is described, with application to small-scale planning and scheduling systems in the Space Station program. The input is a proposed mission profile, including mission duration, number of allowable slip periods, and requirement profiles for one or more resources as a function of time. A corresponding availability profile is also entered for each resource over the whole time interval under study. AUTOPLAN determines all integrated schedules which do not require more than the available resources. IAA

N89-10116# Instituto de Investigacion Tecnologia, Madrid (Spain).

STUDY ON CONCEPTUAL DESIGN OF SPACECRAFT USING COMPUTER-AIDED ENGINEERING TECHNIQUES Final Report

I. J. PEREZ-ARRIAGA, J. J. ALBA, F. CUADRA, J. J. SANGIL, M. ANGULO, and N. BALTEAS Paris, France ESA Dec. 1987 138 p

(Contract ESTEC-6886/85-NL-PP)

(ESA-CR(P)-2615; ETN-88-93149) Avail: NTIS HC A07/MF A01

A formal characterization of the process of conceptual design of spacecraft was derived, and the basic functions and requirements for a Conceptual Design of Spacecraft Tool (CDST) were defined. The major building blocks needed in the CDST were individually analyzed, including: knowledge acquisition procedures; knowledge representation techniques; automatic design approach suitable for computer implementation; decision-making logic adapted to a multiobjective environment; and design process control logic relying on existing artificial intelligence techniques. A possible hardware and software configuration based on existing resources was derived, and a mock-up of a simplified CDST was developed and implemented so that hands-on experience on each major aspect can be obtained. A working plan for a phased/expandable development of the CDST was produced. ESA

N89-11407*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

OEXP ANALYSIS TOOLS WORKSHOP

L. BERNARD GARRETT, ROBERT L. WRIGHT, DEBORAH BADI, and JOHN T. FINDLAY (Flight Mechanics and Control, Inc., Hampton, Va.) Aug. 1988 146 p Workshop held in Hampton, Va., 21-22 Jun. 1988 Sponsored by NASA, Washington, D.C.

(NASA-CP-10013; NAS 1.55:10013) Avail: NTIS HC A07/MF A01 CSCL 09/2

This publication summarizes the software needs and available analysis tools presented at the OEXP Analysis Tools Workshop held at the NASA Langley Research Center, Hampton, Virginia on June 21 to 22, 1988. The objective of the workshop was to identify available spacecraft system (and subsystem) analysis and engineering design tools, and mission planning and analysis software that could be used for various NASA Office of Exploration (code Z) studies, specifically lunar and Mars missions. Author

N89-12582*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.

FIFTEENTH SPACE SIMULATION CONFERENCE: SUPPORT THE HIGHWAY TO SPACE THROUGH TESTING

JOSEPH STECHER, ed. 1988 492 p Conference held in Williamsburg, Va., 31 Oct. - 3 Nov. 1988; sponsored by NASA, Inst. of Environmental Sciences, AIAA, and the American Society for Testing and Materials

(NASA-CP-3015; REPT-88B0253; NAS 1.55:3015) Avail: NTIS HC A21/MF A01 CSCL 22/2

The Institute of Environmental Sciences Fifteenth Space Simulation Conference, Support the Highway to Space Through Testing, provided participants a forum to acquire and exchange information on the state-of-the-art in space simulation, test technology, thermal simulation and protection, contamination, and techniques of test measurements.

N89-13462*# Pennsylvania State Univ., University Park. Dept. of Electrical Engineering.

INFINITE-DIMENSIONAL APPROACH TO SYSTEM IDENTIFICATION OF SPACE CONTROL LABORATORY EXPERIMENT (SCOLE)

S. A. HOSSAIN and K. Y. LEE *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 17-53 Oct. 1988

Avail: NTIS HC A17/MF A01 CSCL 22/2

The identification of a unique set of system parameters in large space structures poses a significant new problem in control technology. Presented is an infinite-dimensional identification scheme to determine system parameters in large flexible structures in space. The method retains the distributed nature of the structure throughout the development of the algorithm and a finite-element approximation is used only to implement the algorithm. This approach eliminates many problems associated with model truncation used in other methods of identification. The identification is formulated in Hilbert space and an optimal control technique is used to minimize weighted least squares of error between the actual and the model data. A variational approach is used to solve the problem. A costate equation, gradients of parameter variations and conditions for optimal estimates are obtained. Computer simulation studies are conducted using a shuttle-attached antenna configuration, more popularly known as the Space Control Laboratory Experiment (SCOLE) as an example. Numerical results show a close match between the estimated and true values of the parameters. Author

N89-13895*# Hamilton Standard Div., United Aircraft Corp., Windsor Locks, CT.

APPENDICES TO THE MODEL DESCRIPTION DOCUMENT FOR A COMPUTER PROGRAM FOR THE EMULATION/SIMULATION OF A SPACE STATION ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM

JAMES L. YANOSY Sep. 1988 106 p

(Contract NAS1-17397)

(NASA-CR-181738; NAS 1.26:181738; SVHSER-10638) Avail: NTIS HC A06/MF A01 CSCL 05/8

A Model Description Document for the Emulation Simulation Computer Model was already published. The model consisted of a detailed model (emulation) of a SAWD CO2 removal subsystem which operated with much less detailed (simulation) models of a cabin, crew, and condensing and sensible heat exchangers. The purpose was to explore the utility of such an emulation simulation combination in the design, development, and test of a piece of ARS hardware, SAWD. Extensions to this original effort are presented. The first extension is an update of the model to reflect changes in the SAWD control logic which resulted from test. Also, slight changes were also made to the SAWD model to permit restarting and to improve the iteration technique. The second extension is the development of simulation models for more pieces of air and water processing equipment. Models are presented for: EDC, Molecular Sieve, Bosch, Sabatier, a new condensing heat exchanger, SPE, SFWES, Catalytic Oxidizer, and multifiltration. The third extension is to create two system simulations using these models. The first system presented consists of one air and one water processing system. The second consists of a potential air revitalization system. Author

N89-13896*# Hamilton Standard Div., United Aircraft Corp., Windsor Locks, CT.

APPENDICES TO THE USER'S MANUAL FOR A COMPUTER PROGRAM FOR THE EMULATION/SIMULATION OF A SPACE STATION ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM

JAMES L. YANOSY Sep. 1988 208 p
(Contract NAS1-17397)
(NASA-CR-181736; NAS 1.26:181736; SVHSER-10639) Avail: NTIS HC A10/MF A01 CSCL 05/8

A user's Manual for the Emulation Simulation Computer Model was published previously. The model consisted of a detailed model (emulation) of a SAWD CO2 removal subsystem which operated with much less detailed (simulation) models of a cabin, crew, and condensing and sensible heat exchangers. The purpose was to explore the utility of such an emulation/simulation combination in the design, development, and test of a piece of ARS hardware - SAWD. Extensions to this original effort are presented. The first extension is an update of the model to reflect changes in the SAWD control logic which resulted from the test. In addition, slight changes were also made to the SAWD model to permit restarting and to improve the iteration technique. The second extension is the development of simulation models for more pieces of air and water processing equipment. Models are presented for: EDC, Molecular Sieve, Bosch, Sabatier, a new condensing heat exchanger, SPE, SFWES, Catalytic Oxidizer, and multifiltration. The third extension is to create two system simulations using these models. The first system presented consists of one air and one water processing system, the second a potential Space Station air revitalization system. Author

N89-13897*# Hamilton Standard Div., United Aircraft Corp., Windsor Locks, CT.
USER'S MANUAL FOR A COMPUTER PROGRAM FOR THE EMULATION/SIMULATION OF A SPACE STATION ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM (ESCM)
JAMES L. YANOSY Sep. 1988 216 p
(Contract NAS1-17397)
(NASA-CR-181735; NAS 1.26:181735; SVHSER-9503) Avail: NTIS HC A10/MF A01 CSCL 05/8

This manual describes how to use the Emulation Simulation Computer Model (ESCM). Based on G189A, ESCM computes the transient performance of a Space Station atmospheric revitalization subsystem (ARS) with CO2 removal provided by a solid amine water desorbed subsystem called SAWD. Many performance parameters are computed some of which are cabin CO2 partial pressure, relative humidity, temperature, O2 partial pressure, and dew point. The program allows the user to simulate various possible combinations of man loading, metabolic profiles, cabin volumes and certain hypothesized failures that could occur. Author

N89-15163*# California Univ., Los Angeles.
A MATHEMATICAL FORMULATION OF THE SCOLE CONTROL PROBLEM. PART 2: OPTIMAL COMPENSATOR DESIGN Final Report
A. V. BALAKRISHNAN Dec. 1988 24 p
(Contract NAG1-464)
(NASA-CR-181720; NAS 1.26:181720) Avail: NTIS HC A03/MF A01 CSCL 22/2

The study initiated in Part 1 of this report is concluded and optimal feedback control (compensator) design for stability augmentation is considered, following the mathematical formulation developed in Part 1. Co-located (rate) sensors and (force and moment) actuators are assumed, and allowing for both sensor and actuator noise, stabilization is formulated as a stochastic regulator problem. Specializing the general theory developed by the author, a complete, closed form solution (believed to be new with this report) is obtained, taking advantage of the fact that the inherent structural damping is light. In particular, it is possible to solve in closed form the associated infinite-dimensional steady-state Riccati equations. The SCOLE model involves associated partial differential equations in a single space variable, but the compensator design theory developed is far more general since it is given in the abstract wave equation formulation. The results thus hold for any multibody system so long as the basic model is linear. Author

N89-15554*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
THE ELEMENTS OF DESIGN KNOWLEDGE CAPTURE
MICHAEL S. FREEMAN *In its* Fourth Conference on Artificial Intelligence for Space Applications p 39-46 Oct. 1988
Avail: NTIS HC A21/MF A01 CSCL 09/2

This paper will present the basic constituents of a design knowledge capture effort. This will include a discussion of the types of knowledge to be captured in such an effort and the difference between design knowledge capture and more traditional knowledge base construction. These differences include both knowledge base structure and knowledge acquisition approach. The motivation for establishing a design knowledge capture effort as an integral part of major NASA programs will be outlined, along with the current NASA position on that subject. Finally the approach taken in design knowledge capture for Space Station will be contrasted with that used in the HSTDEK project. Author

N89-15567*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
AUTOMATIC DETECTION OF ELECTRIC POWER TROUBLES (ADEPT)
CAROLINE WANG, HUGH ZEANAH, AUDIE ANDERSON, CLINT PATRICK, MIKE BRADY, and DONNIE FORD (Alabama Univ., Huntsville.) *In its* Fourth Conference on Artificial Intelligence for Space Applications p 125-130 Oct. 1988
Avail: NTIS HC A21/MF A01 CSCL 09/2

ADEPT is an expert system that integrates knowledge from three different suppliers to offer an advanced fault-detection system, and is designed for two modes of operation: real-time fault isolation and simulated modeling. Real time fault isolation of components is accomplished on a power system breadboard through the Fault Isolation Expert System (FIES II) interface with a rule system developed in-house. Faults are quickly detected and displayed and the rules and chain of reasoning optionally provided on a Laser printer. This system consists of a simulated Space Station power module using direct-current power supplies for Solar arrays on three power busses. For tests of the system's ability to locate faults inserted via switches, loads are configured by an INTEL microcomputer and the Symbolics artificial intelligence development system. As these loads are resistive in nature, Ohm's Law is used as the basis for rules by which faults are located. The three-bus system can correct faults automatically where there is a surplus of power available on any of the three busses. Techniques developed and used can be applied readily to other control systems requiring rapid intelligent decisions. Simulated modelling, used for theoretical studies, is implemented using a modified version of Kennedy Space Center's KATE (Knowledge-Based Automatic Test Equipment), FIES II windowing, and an ADEPT knowledge base. A load scheduler and a fault recovery system are currently under development to support both modes of operation. Author

N89-16300*# Productivity Research Corp., Cape Canaveral, FL.
SOME DESIGN CONSTRAINTS REQUIRED FOR THE USE OF GENERIC SOFTWARE IN EMBEDDED SYSTEMS: PACKAGES WHICH MANAGE ABSTRACT DYNAMIC STRUCTURES WITHOUT THE NEED FOR GARBAGE COLLECTION
CHARLES S. JOHNSON *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 1 9 p 1986
Avail: NTIS HC A18/MF A01 CSCL 09/2

The embedded systems running real-time applications, for which Ada was designed, require their own mechanisms for the management of dynamically allocated storage. There is a need for packages which manage their own internalo structures to control their deallocation as well, due to the performance implications of garbage collection by the KAPSE. This places a requirement upon the design of generic packages which manage generically structured private types built-up from application-defined input types. These kinds of generic packages should figure greatly in the development of lower-level software such as operating systems,

schedulers, controllers, and device driver; and will manage structures such as queues, stacks, link-lists, files, and binary multary (hierarchical) trees. Controlled to prevent inadvertent de-designation of dynamic elements, which is implicit in the assignment operation A study was made of the use of limited private type, in solving the problems of controlling the accumulation of anonymous, detached objects in running systems. The use of deallocator prodecures for run-down of application-defined input types during deallocation operations during satellites. Author

N89-19345# Harris Corp., Melbourne, FL. Government Aerospace Systems Div.
THE OPTIMAL PROJECTION EQUATIONS FOR FIXED-ORDER DYNAMIC COMPENSATION: EXISTENCE, CONVERGENCE AND GLOBAL OPTIMALITY
DAVID C. HYLAND *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 65-72 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

Regardless of how appealing the optimal projection formulation may appear to be, its contribution is vacuous unless certain serious questions can be resolved. These include: (1) Under what conditions can the optimal projection equations be guaranteed a priori to possess a solution. (2) Given problem data, exactly how many solutions do the equations possess. (3) Of the possible solutions, what are their stability properties, what is their performance, and which is the global optimum. (4) How can numerical algorithms be constructed which can be guaranteed to converge to any desired solution especially the global minimum. It seems clear that any attempt to address the above issues must utilize mathematical methods which are global in nature. To this end we have applied degree theory and associated homotopic continuation methods to analyze the solutions to the optimal projection equations and to construct convergent, implementable algorithms for their computation. The purpose of this presentation is to report significant recent results in this regard. Author

N89-19348# Lawrence Livermore National Lab., CA.
A CONTROLLED COMPONENT SYNTHESIS METHOD FOR TRUSS STRUCTURE VIBRATION CONTROL
K. DAVID YOUNG *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 81-83 11 Dec. 1987
(Contract W-7405-ENG-48)
Avail: NTIS HC A05/MF A01 CSCL 22/5

A new framework for the design of controllers for truss structure vibration control which is closely related to that of the Subsystem Decomposition Approach is introduced. The method developed herein deviates from conventional control system design practice in which a dynamic model of the open loop plant is often the initial data given to the control system designer. Instead, the controlled plant is assembled from the controlled components in the control design process. The development of this controlled component synthesis method is motivated on one hand by the well developed component mode synthesis methods (8 to 10) - a collection of structural analysis methods which has been demonstrated to be effective for solving large complex structural analysis problems for almost three decades, and on the other, stimulated by the subsystem decomposition viewpoint in large scale system theory. Connections between controlled component synthesis and existing large scale system decomposition techniques are established herein to build a control theoretic foundation for the developed method. A simple truss vibration control problem has been employed to illustrate the design procedures, as well as demonstrating the potentials of the developed method for controlling very large dimensional repetitive truss structures. Author

03

STRUCTURAL CONCEPTS

Includes analyses and descriptions of different Space Station structural concepts, arrangements, testing, methods of construction and/or manufacturing and specific rotary joints, structural nodes, and columns.

A89-10119*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RECENT DEVELOPMENTS IN THE EXPERIMENTAL IDENTIFICATION OF THE DYNAMICS OF A HIGHLY FLEXIBLE GRID
RAYMOND C. MONTGOMERY and TERRI LAZARUS (NASA, Langley Research Center, Hampton, VA) ASME, Winter Annual Meeting, 108th, Boston, MA, Dec. 13-18, 1987. 8 p. refs
(ASME PAPER 87-WA/DSC-19)

Control effectiveness tests of reaction wheel actuators attached to a highly flexible grid are reported. Analytic determination of actuator control effectiveness is accomplished with finite-element modeling. Experimental determination is done with a least-square parameter identification algorithm that identifies the control coefficients of the second-order difference equation model of each vibration mode. The algorithm assumes a model with frequency and damping predetermined from free-decay tests for each mode. Accounting for the difference in forced and resonant frequency was necessary to produce control effectiveness estimates that are in reasonable agreement with the analytic predictions. The average error for control effectiveness coefficients greater than 5/sq sec was 6.384 percent. Author

A89-10533
STRUCTURAL DYNAMICS PROBLEMS OF FUTURE SPACECRAFT SYSTEMS - NEW SOLUTION METHODS AND PERSPECTIVES [STRUKTURDYNAMISCHE PROBLEME ZUKUENFTIGER RAUMFAHRTSYSTEME - NEUE LOESUNGSKONZEPTE UND PERSPEKTIVEN]
E. BREITBACH and H. HUENERS (DFVLR, Institut fuer Aeroelastik, Goettingen, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 395-405. In German. refs
(DGLR PAPER 87-126)

The mechanical and thermal loads imposed on spacecraft and payloads during launch and reentry, the methods used to predict and simulate these loads, and the design implications of typical loading levels are reviewed, with reference to the FRG Planning Framework for High Technology and Space Flight. A typical satellite mission profile is shown; the structural-dynamic qualification process is outlined; system identification methods are described in detail; and the fundamental principles of passive and active vibration control are discussed. Extensive diagrams, drawings, graphs, and photographs are provided. T.K.

A89-10541#
A STUDY ON GROUND TESTING METHOD FOR LARGE DEPLOYMENT ANTENNA
AKIRA MEGURO Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663), vol. 36, no. 414, 1988, p. 326-332. In Japanese, with abstract in English. refs

The ground testing of large antenna deployment is important in verifying it's deployment capability in geostationary orbit. But the exact simulation of deployment motion by ground testing is significantly inhibited due to prominent gravitational or atmospheric effects on deployment motion. As a part of verification activity, the object of this study is to estimate the influence of these ground effects on deployment motion quantitatively and to define the best method for ground deployment tests. Ground testing equipment was constructed in such a way that gravity effects were canceled by means of a suspending reflector from the point at 10 m high.

Careful consideration was given to friction torque and air drug torque in simple model tests. Results closely correspond to the results of ground testing for an actual antenna reflector. Author

A89-10570#
SOME BASIC EXPERIMENTS ON VIBRATION CONTROL OF AN ELASTIC BEAM SIMULATING FLEXIBLE SPACE STRUCTURE
HARUO KIMURA, NORIHIRO GOTO, YOSHIRO OKA, HIDEHIRO FUKUDA, KAZUO TSUCHIYA et al. Kyushu University, Technology Reports (ISSN 0023-2718), vol. 61, June 1988, p. 301-308. In Japanese, with abstract in English. refs

An experimental apparatus has been developed for testing control strategies for suppressing the vibration of flexible structure model attached to a movable rigid body in connection with the control problems of flexible space structures. The rigid body has a vertical shaft which is magnetically suspended and free to rotate about its axis, and the magnetic bearing is mounted on a table that can be driven linearly by means of a ball-screw and d-c servomotor device. Accordingly, the flexible model, an elastic beam in the present case, can be given rotational and translational motion superimposed to its own elastic deformation. Frictionless sensors and actuators are prepared to measure and control the disturbed motion of the model. Some experimental results are presented which demonstrate the usefulness of the present apparatus for testing interaction between the elastic and the rigid modes of motion by applying the method of displacement and velocity feedback control to the model. Author

A89-10648* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
LARGE SPACE STRUCTURES - STRUCTURAL CONCEPTS AND MATERIALS
CHARLES P. BLANKENSHIP and ROBERT J. HAYDUK (NASA, Langley Research Center, Hampton, VA) IN: International Pacific Air and Space Technology Conference, Melbourne, Australia, Nov. 13-17, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 243-271. refs
(SAE PAPER 872429)

Large space structures will be a key element of future space activities. They will include spacecraft such as the planned Space Station and large antenna/reflector structures for communications and observations. These large structures will exceed 100 m in length or 30 m in diameter. This paper provides an overview of research in the space construction of large structures including erectable and deployable concepts. Also, an approach to automated, on-orbit construction is presented. Materials research for space applications focuses on high stiffness, low expansion composite materials that provide adequate durability in the space environment. The status of these materials research activities is discussed. Author

A89-10918
VIBRATION CONTROL OF A FLEXIBLE MANIPULATOR WITH THREE DEGREES OF FREEDOM
YOSHIYUKI SAKAWA (Osaka University, Japan) IN: Recent advances in communication and control theory. New York, Optimization Software, Inc., 1987, p. 239-261. refs

A flexible manipulator having a parallel drive mechanism and three degrees of freedom is treated. Only the forearm of the manipulator is assumed to be flexible because it is slender and carries a heavy end-effector. Both the elastic vibration of the arm which occurs owing to flexibility and the positions of driving motors should be controlled simultaneously. Partial differential equations and boundary conditions that govern the elastic vibration of the arm are derived. On the basis of a finite-dimensional modal model of the distributed parameter system, an optimal feedback control system is constructed by using the outputs of several sensors. Author

A89-11094
FLEXIBILITY CONTROL OF FLEXIBLE STRUCTURES - MODELING AND CONTROL METHOD OF BENDING-TORSION COUPLED VIBRATIONS
TOSHIO FUKUDA, FUMIHITO ARAI, HIDEMI HOSOGAI (Tokyo, Science University, Japan), and NOBUYUKI YAJIMA (Tokyo, University, Japan) JSME International Journal, Series III (ISSN 0914-8825), vol. 31, Sept. 1988, p. 575-582. refs

This paper describes a modeling of bending-torsion coupled vibrations of flexible structures, such as solar battery arrays, and a control method based on this model. The bending-torsion coupled vibrations are modeled by the unconstrained mode method in the case that the center of flexure does not coincide with the centroid in the cross section. The system and the observation equations of this system are derived after the modal decomposition. Considering the state feedback control system with the state estimator, we elucidate the effect of the coupling terms in this system. Furthermore, a control method to deal with noise contamination of the sensors is also shown. Finally, some simulation results of the bending-torsion coupled vibration control are presented. Author

A89-11656#
SQUARE ROOT FILTERING FOR CONTINUOUS-TIME MODELS OF LARGE SPACE STRUCTURES
Y. OSHMAN and D. J. INMAN (New York, State University, Buffalo) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 61-75. refs

This paper presents a filtering method which exploits the special properties of large flexible structure models. In particular, a new square root filtering method is presented for a class of second order, continuous-time stochastic models of flexible structures. The method is based on the spectral decomposition of the estimation error covariance matrix into its V-Lambda factors, where V is the matrix whose columns are the covariance eigenvectors and Lambda is the diagonal matrix of eigenvalues. Author

A89-11658#
DECENTRALIZED CONTROL OF LARGE-SCALE SYSTEMS
F. M. PITMAN and M. AHMADIAN (Clemson University, SC) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 103-118. Research supported by USAF, Eastman Kodak Co., and Clemson University. refs

Decentralized control of large-scale modular type structures, similar to those intended for use in space, is addressed. A two-level control strategy consisting of local and global controllers is used to control the system. The global controllers are used to minimize the effect of coupling and the local controllers are employed to accomplish optimal performance and stability. A set of stability conditions based on the properties of the subsystems is presented for the overall system. Finally, a system consisting of two simply supported beams coupled by a spring is used to demonstrate the application of the method and the effects of coupling on the proposed control strategy. Author

A89-11660#
EVALUATION OF TWO IDENTIFICATION METHODS FOR DAMAGE DETECTION IN LARGE SPACE TRUSSES
S. WEAVER SMITH and S. L. HENDRICKS (Virginia Polytechnic Institute and State University, Blacksburg) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 127-141.

Two methods of system identification are evaluated with respect to the application of damage detection for large space trusses. The first method, developed by Kabe (1985), uses the known physical connectivity of the structure to preclude unreasonable couplings while identifying the elements of the stiffness matrix.

White and Maytum (1976) developed a method that uses linear perturbations of submatrices and an energy distribution analysis to identify the elements of the stiffness matrix. Evaluations of these methods were conducted with three test systems - a spring-mass model, a planar truss model, and a three-dimensional truss model patterned after the Space Station truss. Author

A89-11661#
SYSTEM IDENTIFICATION EXPERIMENTS FOR FLEXIBLE STRUCTURE CONTROL
S. YURKOVICH (Ohio State University, Columbus) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 143-157. refs

Several competing methods for parameter estimation and model identification of flexible mechanical structures are discussed. Primary emphasis in the problem formulation is not on extracting structural or modal information from the identification exercise; rather, the focus is on identification of model parameters which are amenable to control applications and design. On-line and off-line techniques are discussed, and simulation and experimental results are presented. Author

A89-11662#
TIME-VARIABLE REDUCED ORDER MODELS - AN APPROACH TO IDENTIFICATION AND ACTIVE SHAPE-CONTROL OF LARGE SPACE STRUCTURES
J. MARCZYK (Tecnomare S.p.A., Milan, Italy) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 159-170. refs

The paper describes an approach to the identification/active configuration-control problem of exceptionally large space structures (LSS) characterized by low and clustered eigenfrequencies. A time-dependent compensator is suggested for control of such systems. A large number of discrete displacement and velocity sensors are employed to determine uniquely the excited states which become the basis of a control-design reduced order model (ROM). Combining this approach with local feedback leads to an efficient distribution of the control effort in both frequency and space. The suggested control strategy is tested by computer simulations of a free-free beam. Author

A89-11663*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
A RAYLEIGH-RITZ APPROACH TO STRUCTURAL PARAMETER IDENTIFICATION
L. MEIROVITCH, M. A. NORRIS (Virginia Polytechnic Institute and State University, Blacksburg), and J. P. WILLIAMS (NASA, Langley Research Center, Hampton, VA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 171-183. refs
(Contract NAG1-225)

This paper is concerned with the identification of parameter distributions in large space structures. The formulation is based on a Rayleigh-Ritz type approach working with the actual displacement at a given number of points in the structure. The parameter distributions are expanded in terms of known admissible functions multiplied by unknown coefficients, and the identification process reduces to the determination of these coefficients. The procedure uses a perturbation approach, beginning with a postulated set of parameters and iterating to the actual values in an incremental fashion. Author

A89-11664#
'DAISY' - A LABORATORY FACILITY TO STUDY THE CONTROL OF LARGE FLEXIBLE SPACECRAFT
G. B. SINCARSIN, W. G. SINCARSIN (Dynacon Enterprises, Ltd., Downsview, Canada), P. C. HUGHES (Toronto, University, Downsview, Canada), and A. H. REYNAUD (CDC, Communications Research Centre, Ottawa, Canada) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 185-200. CDC-NSERC-supported research.

Approximately five years ago, the Canadian Department of Communications began to fund the design and construction of Daisy - a structure suitable for carrying out laboratory experiments on the control of flexible structures. Now completed, the Daisy structure has three rigid and 20 elastic degrees of freedom, very low frequencies (about 0.1 Hz), very low damping (about 0.6 percent), 'clustered' modes, and the potential to study both attitude control and shape control. This paper briefly describes Daisy and the sensors and actuators with which it is currently endowed. Sensors include digital encoders for 'attitude' measurements, and accelerometers; actuators include three reaction wheels, and thrusters. Author

A89-11666*# Catholic Univ. of America, Washington, DC.
OPTIMUM VIBRATION CONTROL OF FLEXIBLE BEAMS BY PIEZO-ELECTRIC ACTUATORS
A. BAZ, S. POH (Catholic University of America, Washington, DC), and P. STUDER (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 217-234. Previously announced in STAR as N87-18880. refs
(Contract NAG5-520)

The utilization of piezoelectric actuators in controlling the structural vibrations of flexible beams is examined. A Modified Independent Modal Space Control (MIMSC) method is devised to enable the selection of the optimal location, control gains and excitation voltage of the piezoelectric actuators in a way that would minimize the amplitudes of vibrations of beams to which these actuators are bonded, as well as the input control energy necessary to suppress these vibrations. The developed method accounts for the effects that the piezoelectric actuators have on changing the elastic and inertial properties of the flexible beams. Numerical examples are presented to illustrate the application of the developed MIMSC method in minimizing the structural vibrations of beams of different materials when subjected to different loading and end conditions using ceramic or polymeric piezoelectric actuators. The obtained results emphasize the importance of the devised method in designing more realistic active control systems for flexible beams, in particular, and large flexible structures in general. Author

A89-11667#
A LABORATORY FACILITY FOR FLEXIBLE STRUCTURE CONTROL EXPERIMENTS
U. OZGUNER, S. YURKOVICH, J. MARTIN, and P. KOTNIK (Ohio State University, Columbus) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 235-250. Research supported by Whirlpool Co. refs
(Contract NSF DMC-85-06143)

A laboratory facility to study various control problems related to flexible mechanical structures has been developed. Various experimental configurations that address generic problems in large flexible space structures and flexible robotic manipulators have been, and are being, developed. While problems in vibration damping and slewing are being considered from the view point of modeling, identification and control, a major part of the effort is also directed toward true actuation, sensing, and feedback implementation issues. Author

A89-11674#
ON THE ACTIVE VIBRATION CONTROL OF DISTRIBUTED PARAMETER SYSTEMS
P. HAGEDORN and J. T. SCHMIDT (Darmstadt, Technische

Hochschule, Federal Republic of Germany) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 359-373. Research supported by the Stiftung Volkswagenwerk. refs

In this paper the traveling wave approach is discussed for the vibration control of networks of slender flexible structural components. The results previously obtained for the wave equation with the traveling wave approach are reviewed. After the discussion of the wave equation, an active vibration control is then designed for the Timoshenko beam in a similar way. To this end, the equations of motion of the Timoshenko beam are used in the normal form of a hyperbolic system. Results of numerical simulations are also presented. Author

A89-11675#
OBSERVABILITY OF A BERNOULLI-EULER BEAM USING PVF2 AS A DISTRIBUTED SENSOR
S. E. MILLER and J. HUBBARD (Charles Stark Draper Laboratory, Inc., Cambridge, MA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 375-390. refs

A theoretical model for spatially distributed sensors on a flexible beam was derived without the necessity of modeling the beam in terms of its component vibrational modes. The model provides insight into the observability of beams with nearly arbitrary boundary conditions. The sensor distribution may be spatially shaped so as to function similar to point sensors or to produce a signal in which certain vibrational modes of the structure are weighted more than others. The model was verified for the first three modes of a cantilever beam. Spatially uniform and linear-varying sensors constructed from polyvinylidene fluoride (PVF2) were applied to a clamped-free beam. In further experimentation both PVF2 sensors and actuators were used as the active components of a vibration isolation system. Author

A89-11681*# Catholic Univ. of America, Washington, DC.
MODIFIED INDEPENDENT MODAL SPACE CONTROL METHOD FOR ACTIVE CONTROL OF FLEXIBLE SYSTEMS
A. BAZ, S. POH (Catholic University of America, Washington, DC), and P. STUDER (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 477-493. Previously announced in STAR as N87-23980. refs
(Contract NAG5-520; NAG5-749)

A modified independent modal space control (MIMSC) method is developed for designing active vibration control systems for large flexible structures. The method accounts for the interaction between the controlled and residual modes. It incorporates also optimal placement procedures for selecting the optimal locations of the actuators in the structure in order to minimize the structural vibrations as well as the actuation energy. The MIMSC method relies on an important feature which is based on time sharing of a small number of actuators, in the modal space, to control effectively a large number of modes. Numerical examples are presented to illustrate the application of the method to generic flexible systems. The results obtained suggest the potential of the devised method in designing efficient active control systems for large flexible structures. Author

A89-11685#
OPTIMAL VIBRATION CONTROL OF A FLEXIBLE SPACECRAFT DURING A MINIMUM-TIME MANEUVER
L. MEIROVITCH and Y. SHARONY (Virginia Polytechnic Institute and State University, Blacksburg) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 579-601. refs
(Contract F33615-86-C-3233)

This paper is concerned with the simultaneous maneuver and vibration control of a flexible spacecraft. The problem is solved by means of a perturbation approach whereby the slewing of the spacecraft regarded as rigid represents the zero-order problem and the control of vibration, as well as of perturbations from the rigid-body maneuver, represents the first-order problem. The zero-order control is to be carried out in minimum time, which implies bang-bang control. On the other hand, the first-order control is a time-dependent linear quadratic regulator including integral feedback and prescribed convergence rate. Author

A89-11689#
DYNAMICS SIMULATION OF SPACE STRUCTURES SUBJECT TO CONFIGURATION CHANGE
Y. OHKAMI, O. OKAMOTO, T. KIDA, and I. YAMAGUCHI (National Aerospace Laboratory, Tokyo, Japan) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 647-659. refs

The unified matrix approach is used to develop a computer algorithm capable of simulating the dynamics of complex large space structures with variable configuration. This capability is realized through the use of a generic hinge and constraint index matrices that can handle kinetic and kinematic constraints in a unified manner. The algorithm has been successfully used to simulate a series of manipulator operations including changes in topology and constraint conditions. V.L.

A89-11692*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ANALYSIS AND TEST OF A SPACE TRUSS FOLDABLE HINGE
N. A. NIMMO, G. C. HORNER (NASA, Langley Research Center, Hampton, VA), and J. LAUFER (PRC Kentron, Inc., Hampton, VA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 697-711. refs

The Mini-Mast is a 20-meter long deployable, three-longeron, truss-beam being used to develop analytical and experimental methods for predicting the physical behavior of large space structures. With 57 corner-body hinges and 54 mid-body hinges, the Mini-Mast is highly joint-dominated, necessitating inclusion of the compliance of the joints in analytical models. This study demonstrates an approach for calculating the stiffness properties of a complicated hinge called the mid-body hinge. The process includes detailed modeling with solid-body modeling software and the use of finite element analysis. Load-deflection tests were conducted to determine the axial stiffness of the mid-body hinge. This is compared to the axial stiffness value determined from a finite element analysis. Author

A89-11693*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DESIGN OF GROUND TEST SUSPENSION SYSTEMS FOR VERIFICATION OF FLEXIBLE SPACE STRUCTURES
V. M. COOLEY, J. N. JUANG (NASA, Langley Research Center, Hampton, VA), and P. GHAEMMAGHAMI (Old Dominion University, Norfolk, VA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 713-725. refs

A simple model demonstrates the frequency-increasing effects of a simple cable suspension on flexible test article/suspension systems. Two passive suspension designs, namely a negative spring mechanism and a rolling cart mechanism, are presented to alleviate the undesirable frequency-increasing effects. Analysis methods are provided for systems in which the augmentations are applied to both discrete and continuous representations of test articles. The damping analyses are based on friction equivalent

viscous damping. Numerical examples are given for comparing the two augmentations with respect to minimizing frequency and damping increases. Author

A89-12134
GEOMETRIC NON-LINEAR SUBSTRUCTURING FOR DYNAMICS OF FLEXIBLE MECHANICAL SYSTEMS
SHIH-CHIN WU and EDWARD J. HAUG (Iowa, University, Iowa City) International Journal for Numerical Methods in Engineering (ISSN 0029-5981), vol. 26, Oct. 1988, p. 2211-2226. refs

A procedure for including individual-member geometric nonlinearities in standard FEM analytical models of flexible multibody structures is developed and demonstrated. The limitations imposed by multibody analyses based on linear-elastic small-deformation models of components are discussed, and a unified substructure formulation is derived for small-strain geometric nonlinearities. The procedure is based on the convected-coordinates approach of Belytschko and Hsieh (1973) and Housner (1984), but is independent of the type of finite element employed. The compatibility constraints, the substructure synthesis method, and the selection of the deformation mode are discussed, and numerical results for a rotating beam and a truss space structure are presented in extensive graphs and characterized in detail. T.K.

A89-12573
ON THE EXPLOITATION OF GEOMETRICAL SYMMETRY IN STRUCTURAL COMPUTATIONS OF SPACE POWER STATIONS
ALAIN BOSSAVIT (Electricite de France, Clamart) Space Power (ISSN 0951-5089), vol. 7, no. 2, 1988, p. 199-210. refs

An account is given of the principles of computational structural analysis. Means of exploiting the geometrical symmetry of space structures to save on the computational cost of their mechanical characteristics are discussed. Bilateral symmetry is considered as well as the assembly of elements. K.K.

A89-12635 Howard Univ., Washington, DC.
ORIENTATION AND SHAPE CONTROL OF OPTIMALLY DESIGNED LARGE SPACE STRUCTURES
PETER M. BAINUM and K. SATYANARAYANA (Howard University, Washington, DC) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 133-143. Research supported by Howard University and NASA. refs
(AAS PAPER 87-415)

In this study, the vibration and orientation control of large space structures using the linear quadratic regulator technique is investigated. Emphasis is placed on the control of both a class of optimally designed structures and uniform structures meeting the mission requirements using a long free-free beam in orbit as an example. The open loop and closed loop dynamics are compared and the transient responses are obtained to determine the effectiveness of the control system design. Author

A89-12636
OPTIMAL CONFIGURATION AND TRANSIENT DYNAMIC ANALYSES OF STATICALLY DETERMINATE ADAPTIVE TRUSS STRUCTURES FOR SPACE APPLICATION
KAZUO YAMAMOTO, MASAKI TABATA (Mitsubishi Electric Corp., Central Research Laboratory, Amagasaki, Japan), and KORYO MIURA (Tokyo, University, Japan) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 145-160.
(AAS PAPER 87-417)

Numerical procedures on optimal configuration and transient dynamics are developed for a statically determinate adaptive truss called Variable Geometry Truss. The equations of optimization are formulated so that the change in a geometrical amount from the initial state may be minimized, with constraint conditions relating to the configuration of the truss. Then, transient dynamics toward the optimal configuration is formulated using the energy method with and without consideration of the elasticity of members. Solutions of the nonlinear algebraic and differential equations are successfully obtained by use of the iterative numerical schemes. Author

A89-12647
FLEXIBILITY MODELING METHODS IN MULTIBODY DYNAMICS
R. R. RYAN (Michigan, University, Ann Arbor) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 365-385. refs
(AAS PAPER 87-431)

Methods used in multibody dynamics formalisms to model flexible bodies undergoing large overall motions and small deformations are studied with the aid of a simple example problem. Limitations in the most common modeling approach, involving assumed modes, are pointed out and ramifications are discussed. Two new procedures are presented and the relative merits of computer implementation of each of these are considered. Author

A89-12648
DYNAMICS OF GRAVITY ORIENTED SATELLITES WITH THERMALLY FLEXED APPENDAGES
A. C. NG and V. J. MODI (British Columbia, University, Vancouver, Canada) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 387-410.
(Contract NSERC-G-1547)
(AAS PAPER 87-432)

Equations are presented for the motion of a satellite with a rigid central body and a pair of appendages deforming due to thermal effects of solar radiation. It is shown that, for a circular orbit, the flexible system can become unstable under critical combinations of system parameters and initial conditions although the corresponding rigid system continues to be stable. In the case of eccentric orbits, depending on the initial conditions, thermally flexed appendages can stabilize or destabilize the system. K.K.

A89-12661* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
MODEL REDUCTION IN THE SIMULATION OF INTERCONNECTED FLEXIBLE BODIES
FIDELIS O. EKE and GUY K. MAN (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 603-612. refs
(AAS PAPER 87-455)

Given the control system specifications for a system of interconnected rigid and flexible bodies, methods now exist for determining the system modes that do not interact 'strongly' with the controller. Once these important system modes are known, there still remains the problem of determining the modes of individual bodies that should be retained, since, in the final analysis, it is the modal information at the component level that must be fed into any multibody simulation code. Systematic identification of these component modes is achieved through a two-phase matrix diagonalization process starting with judiciously chosen submatrices of the system modal matrix. Author

A89-15501
INTERNATIONAL MODAL ANALYSIS CONFERENCE, 6TH, KISSIMMEE, FL, FEB. 1-4, 1988, PROCEEDINGS. VOLUMES 1 & 2
Conference sponsored by Union College and SEM. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. Vol. 1, 874 p.; vol. 2, 915 p. For individual items see A89-15502 to A89-15645.

Topics considered include analytical methods, structural dynamic modification, seismic topics, modal test methods, noise/acoustics, experimental techniques, finite element analysis, transducers and instrumentation, linking analysis and test, and

processing modal data. Consideration is also given to space structures, machinery diagnostics, design methods, substructuring, nonlinear structures, system identification and control, and damping. B.J.

A89-15587
ACTIVE VIBRATION CONTROL OF FLEXIBLE STRUCTURE BY EIGENSTRUCTURE ASSIGNMENT TECHNIQUE
Q. ZHANG, JIM Y. H. LIU, RANDALL J. ALLEMANG, and Y. G. TSUEI (Cincinnati, University, OH) IN: International Modal Analysis Conference, 6th, Kissimmee, FL, Feb. 1-4, 1988, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. 1015-1019. refs

A method to control the dynamic response of flexible structures from experimental modal data is investigated. Based on sensitivity analysis, locations of actuators are predetermined. By applying the Eigenstructure Assignment Technique, the desired frequencies, the damping and the mode shapes can be chosen to calculate the feedback gain matrix. From the calculated feedback gain matrix, the feedback loop control system can be designed. Even under unknown external excitation, vibration of some critical points can be suppressed, or constrained to vibrate within certain bounds by the Eigenstructure Assignment Technique. Numerical examples are presented to support this approach. Author

A89-15617
A COMPARISON BETWEEN SINGLE POINT EXCITATION AND BASE EXCITATION FOR SPACECRAFT MODAL SURVEY
YUICHI MURAKOSHI and FUMIHIRO KUWAO (Toshiba Corp., Komukai Works, Kawasaki, Japan) IN: International Modal Analysis Conference, 6th, Kissimmee, FL, Feb. 1-4, 1988, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. 1365-1370.

For large, complex spacecraft structural systems, it is very important to obtain structural dynamic characteristics by modal survey. For obtaining accurate modal parameters, a suitable excitation method, data acquisition method, and data analysis method in the modal survey should be selected. In particular, accurate results will be obtained by good selection of the excitation method. Thsi paper presents a comparison of modal parameters obtained by single point excitation and base excitation in a modal survey of the truss structure. Author

A89-16117#
ADAPTIVE STRUCTURE CONCEPT FOR FUTURE SPACE APPLICATIONS
KORYO MIURA (Tokyo, University, Kanagawa, Japan) and HIROSHI FURUYA (Nagoya University, Japan) AIAA Journal (ISSN 0001-1452), vol. 26, Aug. 1988, p. 995-1002. refs

A concept of an adaptive structure for future space applications is investigated. The definition of the adaptive structure is that the structure can purposefully vary its geometric configuration as well as its physical properties. It is shown that the variable geometry (VG) truss is the basic form of the adaptive structure. It consists of a repetition of an octahedral truss module in which some of the truss members can vary their lengths continuously using actuators. By this mechanism, the VG truss can change its configuration arbitrarily in three-dimensional space while inherent high stiffness is maintained during the transformation. The basic formulations for its geometry, structural errors, and vibrational properties are established. Some applications, including a second-generation manipulator arm, support architecture for a space station, and others, are discussed. The functional model controlled by a computer demonstrates satisfactorily the basic motions of the VG truss. Author

A89-16152#
EXACTLY SOLVING THE WEIGHTED TIME/FUEL OPTIMAL CONTROL OF AN UNDAMPED HARMONIC OSCILLATOR
MARCELO LOPES DE OLIVEIRA E SOUZA (Instituto de Pesquisas Espaciais, Sao Jose dos Campos, Brazil) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 11, Nov.-Dec. 1988, p. 488-494. Research supported by the Conselho Nacional de Desenvolvimento Cientifico e Tecnologico and Instituto de Pesquisas Espaciais. refs

The exact solution presented for the weighted time/fuel optimal control of an undamped harmonic oscillator having one bounded control and any initial state is motivated by the desire to improve the final behavior of Vander Velde (1983) trajectories for large space structures' on-off control. An investigation is accordingly made of the existence, normality, and uniqueness of both the extremals and the optimal solution; numerical comparisons are then made between the approximate and exact solutions according to three criteria. O.C.

A89-16159*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
MANEUVER AND VIBRATION CONTROL OF SCOLE
R. D. QUINN and L. MEIROVITCH (Virginia Polytechnic Institute and State University, Blacksburg) (Guidance, Navigation and Control Conference, Williamsburg, VA, Aug. 18-20, 1986, Technical Papers, p. 115-129) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 11, Nov.-Dec. 1988, p. 542-553. Previously cited in issue 23, p. 3426, Accession no. A86-47415. refs
(Contract NAG1-225)

A89-16161*# Texas Univ., Austin.
BLOCK-KRYLOV COMPONENT SYNTHESIS METHOD FOR STRUCTURAL MODEL REDUCTION
ROY R. CRAIG, JR. (Texas, University, Austin) and ARTHUR L. HALE (General Dynamics Corp., Space Systems Div., San Diego, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 11, Nov.-Dec. 1988, p. 562-570. refs
(Contract NAS9-17254)

A new analytical method is presented for generating component shape vectors, or Ritz vectors, for use in component synthesis. Based on the concept of a block-Krylov subspace, easily derived recurrence relations generate blocks of Ritz vectors for each component. The subspace spanned by the Ritz vectors is called a block-Krylov subspace. The synthesis uses the new Ritz vectors rather than component normal modes to reduce the order of large, finite-element component models. An advantage of the Ritz vectors is that they involve significantly less computation than component normal modes. Both 'free-interface' and 'fixed-interface' component models are derived. They yield block-Krylov formulations paralleling the concepts of free-interface and fixed-interface component modal synthesis. Additionally, block-Krylov reduced-order component models are shown to have special disturbability/observability properties. Consequently, the method is attractive in active structural control applications, such as large space structures. The new fixed-interface methodology is demonstrated by a numerical example. The accuracy is found to be comparable to that of fixed-interface component modal synthesis. Author

A89-16162#
IDENTIFICATION METHOD FOR LIGHTLY DAMPED STRUCTURES
NELSON G. CREAMER (General Research Corp., Arlington, VA) and JOHN L. JUNKINS (Texas A & M University, College Station) (Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2A, p. 163-171) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 11, Nov.-Dec. 1988, p. 571-576. Previously cited in issue 14, p. 2171, Accession no. A87-33669. refs

A89-16964
DISTRIBUTED ACTUATOR CONTROL DESIGN FOR FLEXIBLE BEAMS
SHAWN E. BURKE and JAMES E. HUBBARD, JR. (Charles Stark Draper Laboratory, Inc., Cambridge, MA) Automatica (ISSN 0005-1098), vol. 24, Sept. 1988, p. 619-627. Research supported by Charles Stark Draper Laboratory, Inc. refs

The application of a piezoelectric film actuator to the active vibration control of beams is studied for general boundary

conditions and nonuniform film spatial distributions. It is shown that, while for most boundary configurations a spatially uniform control is appropriate, pinned-pinned, free-free, clamped-sliding, and clamped-clamped beams require nonuniform spatial distributions to be controllable. B.J.

A89-17659#
U.S. SPACE STATION FREEDOM - ORBITAL ASSEMBLY AND EARLY MISSION OPPORTUNITIES
DAVID C. WENSLEY (McDonnell Douglas Astronautics Co., Space Station Div., Huntington Beach, CA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 15 p.
(IAF PAPER 88-065)

The launch and assembly sequence and mission support capabilities of the man-tended and permanently manned modes of the Space Station are discussed. Launch packaging and construction in orbit, extravehicular activities associated with the Space Station, operational phases, mission opportunities, and payloads are examined. R.B.

A89-17660#
IDENTIFICATION OF MODAL PARAMETERS IN LARGE SPACE STRUCTURES
M. SEETHARAMA BHAT (Indian Institute of Science, Bangalore, India) and THOMAS LANGE (DFVLR, Oberpfaffenhofen, Federal Republic of Germany) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 6 p. refs
(IAF PAPER 88-066)

A method for estimating modal parameters in large space structures from transfer function data using the sequential linear least square estimation/conjugate gradient algorithm is studied. The mode shape functions are determined from experimental data using the conjugate gradient algorithm for the best curve fit to the experimental data. The mode shape functions are used to determine the control influence, the output, and the optimal positioning of sensor and actuators. Possible applications of the method are considered. R.B.

A89-17750#
INTRODUCING INTELLIGENCE INTO STRUCTURES
KORYO MIURA (Tokyo, University, Japan) and SABURO MATUNAGA IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 11 p.
(IAF PAPER 88-267)

Intelligent truss structures to be assembled by AI-directed robotic means in orbit will, after sufficient development and optimization, be capable of arbitrarily changing their configuration and sensing their own internal geometry, while the assembly robot furnishes external-geometry data as well as the power required for structure actuators' operation. It is shown that the work space required by such a structure is different from that of a manipulator arm. Work space solutions are presented for continuous models and for general discrete models; the work spaces are oval-shaped. O.C.

A89-17751#
A CONTRIBUTION TO THE STUDY OF THE PRECISE PRESSURIZED STRUCTURES
C. ARDUINI, U. PONZI (Roma I, Universita, Rome, Italy), and M. C. BERNASCONI (Contraves AG, Zurich, Switzerland) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 27 p. refs
(IAF PAPER 88-268)

An analytical study of membrane toroidal inflatable structures for outer space is reported. The analysis determines the most economic configuration for an assembly scheme for a perfect torus. The theoretical models considered include a circular homogeneous isotropic torus reference model, a polygonal approximation model, and a parallel approximation model. The analytical approaches are checked against a numerical Nastran model for the polygonal cut case. C.D.

A89-17753#
A FINITE ELEMENT APPROACH FOR COMPOSITE SPACE STRUCTURES
R. BARBONI, P. GAUDENZI, and P. SANTINI (Roma I, Universita, Rome, Italy) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p. refs
(IAF PAPER 88-273)

A class of finite elements is developed to analyze laminated anisotropic plates for deflections, stresses, natural frequencies, and buckling loads. Particular attention is paid to accurate evaluation of strain field, especially transverse shear strain, due to the three-dimensional character of the problem. Several problems are studied, showing the effects of the aspect ratio and of the Young modulus to shear modulus ratio on bending, vibration, and stability of the plate. The numerical results are compared with those available by classical laminate theory. Author

A89-17754#
CONCEPT OF INFLATABLE ELEMENTS SUPPORTED BY TRUSS STRUCTURE FOR REFLECTOR APPLICATION
SUMIO KATO, YASUHIRO TAKESHITA, YOSHINORI SAKAI (Kawasaki Heavy Industries, Ltd., Aircraft Engineering Div., Kakamigahara, Japan), OSAMU MURAGISHI (Kawasaki Heavy Industries, Ltd., Technical Institute, Akashi, Japan), YUZO SHIBAYAMA (NEC Corp., Space Development Div., Yokohama, Japan) et al. IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 15 p. refs
(IAF PAPER 88-274)

A concept of a modularized inflatable space structure which is composed of inflatable elements supported by truss structure for high-precision reflector missions in relatively near future is proposed to avoid some difficulties of conventional inflatable concept, such as the lack of inside hard points and the precisely accurate manufacturing process. Some fundamental characteristics for surface accuracy of inflatable elements are studied, appropriate truss back-up structure is investigated, and the relevant preliminary test results are described. Some aspects of the application of the concept to space VLBI antenna are also introduced. Author

A89-17758#
EXPERIMENTAL AND THEORETICAL ANALYSIS ON THE EFFECTS OF RESIDUAL STRESSES IN COMPOSITE STRUCTURES FOR SPACE APPLICATIONS
G. BABINI, D. STELLA (Contraves Italiana S.p.A., Rome, Italy), M. MARCHETTI, S. SGUBINI, and S. TIZZI (Roma I, Universita, Rome, Italy) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 17 p. refs
(IAF PAPER 88-284)

The purpose of this study is the determination of the effects of the residual stresses arising in the manufacturing of a sandwich composite structure. A theoretical model, which provides the deformation field and the manufacturing rms error, is developed. The model is applied to a sandwich paraboloidic antenna reflector (core: aluminum alloy; skins: graphite-epoxy laminates) for space applications and it is verified by comparison with experimental test results. To this aim a high precision computerized three-dimensional bench (DEA type) has been employed. Author

A89-17761#
VIBRATION CONTROL OF TRUSS STRUCTURES USING ACTIVE MEMBERS
MICHIHIRO NATORI (Tokyo, University, Sagamihara, Japan), SHOICHI MOTOHASHI (Toshiba Corp., Spacecraft Mechanical Engineering Dept., Kawasaki, Japan), and SOICHI OGURA IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p. refs
(IAF PAPER 88-290)

The vibration control of truss structures has attracted increasing attention due to their possible use in space applications such as Space Station structures. Since the members of truss structures are subjected to axial force, a concept of vibration control by the use of axial active members is expected to give a new feature on vibration control of truss structures compared with the conventional

external force control. The various possibilities of stiffness and damping control are demonstrated through the numerical simulation of a two-dimensional truss beam and a beam structure model. Author

A89-17767#
DYNAMIC SIMULATION OF BIFURCATION IN VIBRATION MODES FOR A CLASS OF COMPLEX SPACE STRUCTURES
YOSHIAKI OHKAMI, OSAMU OKAMOTO, TAKASHI KIDA, and ISAO YAMAGUCHI (National Aerospace Laboratory, Chofu, Japan) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 8 p.
(IAF PAPER 88-317)

Dynamics behavior of Large Space Systems (LSS) may pose unexpected phenomena due to complex mechanical configurations, particularly if the system has a closed kinematical loop. Among such phenomena, bifurcation of vibration modes is investigated in this paper. Using an idealized spacecraft with four rigid links, it is demonstrated by computer simulation that bifurcation can take place at a singular point depending upon the angular velocity relations of the body and point and depending upon the angular velocity relations of the body and the links. It is also described in some detail how the system changes in terms of condition number, degree of freedom, and mode shapes of vibration at the passage of this singular point. Author

A89-18046
OPTIMUM DESIGN OF NONLINEAR SPACE TRUSSES
M. P. SAKA (University of Bahrain, Isa Town) (Institution of Civil Engineers, Institution of Highways and Transportation, British Computer Society, et al., CIVIL-COMP 87: International Conference on Civil and Structural Engineering Computing, 3rd, London, England, Sept. 22-24, 1987) Computers and Structures (ISSN 0045-7949), vol. 30, no. 3, 1988, p. 545-551. refs

A structural optimization algorithm which takes into account the nonlinear response of a structure beyond the elastic limit is developed and demonstrated. The derivation is given in detail, and results for sample problems involving space truss structures with 9, 24, 42, and 56 bars are presented in extensive tables and graphs. The algorithm is shown to give accurate results while requiring significantly greater computation time than methods without nonlinear analysis. T.K.

A89-19716
MODAL TESTING AN IMMENSE FLEXIBLE STRUCTURE USING NATURAL AND ARTIFICIAL EXCITATION
T. G. CARNE, J. P. LAUFFER, A. J. GOMEZ (Sandia National Laboratories, Albuquerque, NM), and H. BENJANNET (Shawinigan Engineering Co., Montreal, Canada) International Journal of Analytical and Experimental Modal Analysis (ISSN 0886-9367), vol. 3, Oct. 1988, p. 117-122. refs

Results are presented from a modal test of the 110-m tall EOLE wind turbine which had four modal frequencies below 1.0 Hz. The structure was excited by step relaxation and wind. It was possible to extract modal data from measured frequency response functions using step relaxation in spite of high winds. K.K.

A89-20193*# Carnegie-Mellon Univ., Pittsburgh, PA.
TRANSIENT RESPONSE OF JOINT-DOMINATED SPACE STRUCTURES - A NEW LINEARIZATION TECHNIQUE
J. H. GRIFFIN, J. BIELAK (Carnegie-Mellon University, Pittsburgh, PA), and G. A. FOELSCHE (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 3, p. 1423-1432) AIAA Journal (ISSN 0001-1452), vol. 26, Oct. 1988, p. 1278-1285. Previously cited in issue 12, p. 1909, Accession no. A88-32325. refs
(Contract NAG1-612)

A89-20574
STRUCTURAL CONCEPTS FOR FUTURE SPACE SYSTEMS
JAMES H. BRAHNEY Aerospace Engineering (ISSN 0736-2536), vol. 8, Dec. 1988, p. 10-14.

The NASA Space Station's baseline configuration, at 125 m in length and 100 m in width, exemplifies large space structures for which developments in materials, assembly techniques, and dynamic stability and control methods must be significantly advanced. During the early planning stages, it was determined that a planar truss structure would both meet design requirements and permit growth and versatility; a 5-m strut length has been adopted. Attention is presently given to the beam structures, truss structures, and deployable folding-truss structures that have been devised and evaluated, as well as to the Mobile Remote Manipulator System that has been developed for their erection in orbit. O.C.

A89-20587
TECHNIQUES FOR THE IDENTIFICATION OF DISTRIBUTED SYSTEMS USING THE FINITE ELEMENT APPROXIMATION
K. Y. LEE (Pennsylvania State University, University Park) IN: Control and dynamic systems. Volume 27. Part 3. San Diego, CA, Academic Press, Inc., 1988, p. 183-215. refs

Two approaches to the parameter identification of distributed systems is considered. The first is the infinite-dimensional formulation of the identification problem, while the second is the finite-dimensional formulation of the identification problem. It is found that the finite-element method is a very useful tool in solving the parameter identification problem. K.K.

A89-20838
A STEREO-TRIANGULATION APPROACH TO SENSING FOR STRUCTURAL IDENTIFICATION
JOHN L. JUNKINS and GEORGE H. JAMES, III (Texas A & M University, College Station) IN: Guidance and control 1988; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 30-Feb. 3, 1988. San Diego, CA, Univelt, Inc., 1988, p. 155-165. refs
(AAS PAPER 88-015)

A stereo-optical triangulation approach to making a large number of spatially distributed structural response measurements is discussed. The close-range photogrammetric triangulation achieved in-orbit with the 1984 Shuttle mission is described and means of improving this technique are proposed. Particular attention is given to the incorporation of unique subsystems for analog edge detection and video processing algorithms. K.K.

A89-20847* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
MOMENTUM MANAGEMENT STRATEGY DURING SPACE STATION BUILDUP
LYNDA BISHOP (NASA, Johnson Space Center, Houston, TX), HARVEY MALCHOW, and PHILIP HATTIS (Charles Stark Draper Laboratory, Inc., Cambridge, MA) IN: Guidance and control 1988; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 30-Feb. 3, 1988. San Diego, CA, Univelt, Inc., 1988, p. 315-336. refs
(Contract NAS9-17560)
(AAS PAPER 88-042)

The use of momentum storage devices to control effectors for Space Station attitude control throughout the buildup sequence is discussed. Particular attention is given to the problem of providing satisfactory management of momentum storage effectors throughout buildup while experiencing variable torque loading. Continuous and discrete control strategies are compared and the effects of alternative control moment gyro strategies on peak momentum storage requirements and on commanded maneuver characteristics are described. K.K.

A89-22505*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TRANSMISSION-ZERO BOUNDS FOR LARGE SPACE STRUCTURES, WITH APPLICATIONS
TREVOR WILLIAMS (NASA, Langley Research Center, Hampton, VA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Jan.-Feb. 1989, p. 33-38. Research supported by SERC. refs

Many large space structure control problems lead quite naturally to the application of an optimal regulator, so the transmission

zeros of the open-loop system give fundamental information about the speed of response achievable by the closed-loop system. Despite the importance of this and other well-known zeros properties, little attention has been given to the transmission zeros of large space structures, except for the special case of a rigid spacecraft with flexible appendages. The object of this paper is to remedy this deficiency. In particular, it is proved that the zeros of a structure with colocated sensors and actuators must lie in a region of the complex plane that is defined by its natural frequencies and damping ratios. This generic result, a consequence of the special form of the equations of motion of structural dynamics, admits a very simple graphical interpretation: it is the generalization of the classical pole-zero interlacing property of undamped single-input/single-output structures. The number of sensor/actuator pairs, and their locations, specify where in the permissible region transmission zeros actually lie, thus quantifying the effect of sensor/actuator placement on closed-loop system performance. These points are illustrated by simple examples.
Author

A89-22512#
ROBUSTNESS OPTIMIZATION OF STRUCTURAL AND CONTROLLER PARAMETERS
KYONG B. LIM (Virginia Polytechnic Institute and State University, Blacksburg) and JOHN L. JUNKINS (Texas A & M University, College Station) (Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1, p. 351-361) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Jan.-Feb. 1989, p. 89-96. Previously cited in issue 14, p. 2204, Accession no. A87-33591. refs
(Contract F49620-86-K-0014)

A89-23510
(M, N)-APPROXIMATION - A SYSTEM SIMPLIFICATION METHOD
AJMAL YOUSUFF (Drexel University, Philadelphia, PA), TIMOTHY E. MCQUADE, and SIVAS S. BANDA (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) International Journal of Control (ISSN 0020-7179), vol. 48, Nov. 1988, p. 1851-1865. refs
(Contract F49620-85-C-0013)

Techniques for reducing the complexity of models of large structural systems are developed analytically. An (M, N) approximation procedure which reduces a system of N interacting subsystems to a model comprising only M subsystems while accounting for all of the original interactions, is derived in detail and applied to the balancing problem of a linear-quadratic Gaussian controller. Numerical results demonstrating the efficiency of the method are presented in graphs and discussed. T.K.

A89-24496
FAILURE DETECTION AND IDENTIFICATION IN THE CONTROL OF LARGE SPACE STRUCTURES
H. OKUBO, Y. MUROTSU, and F. TERUI (Osaka Prefecture, University, Sakai, Japan) IN: Automatic control; Proceedings of the Tenth Triennial World Congress of IFAC, Munich, Federal Republic of Germany, July 27-31, 1987. Volume 6. Oxford, England and Elmsford, NY, Pergamon Press, 1988, p. 175-180. refs

Numerical techniques for detecting and isolating faults in structural control systems are described and demonstrated. The governing equations for a linear dynamical system are derived, and a procedure based on the combined use of a decoupled Kalman bias filter and a generalized-likelihood-ratio method is outlined. Results from a simulation of tendon control of a large beam structure (Murotsu et al., 1985) are presented in tables and graphs and briefly characterized. T.K.

A89-25404*# TRW, Inc., Redondo Beach, CA.
METEOROID AND ORBITAL DEBRIS SHIELDING ON THE ORBITAL MANEUVERING VEHICLE
MARC E. KIRKPATRICK (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(Contract NAS8-36800)
(AIAA PAPER 89-0495)

NASA's Orbital Maneuvering Vehicle (OMV) is being designed to withstand a 10-year lifetime in polar and low earth orbits. A large percentage of OMV's lifetime will be spent operating in the vicinity of the Space Shuttle and Space Station or in storage at these manned locations. An extensive analysis has been performed to determine the effects of the meteoroid and orbital debris environments on OMV's external fuel tanks. A finite element model of OMV was constructed using NASTRAN and analyzed with the meteoroid and debris design analysis code BUMPER. The results show that the long design lifetime, and the ever increasing man-made orbital debris environment, will require the use of shielding over the external fuel tanks. Author

A89-25434#
ADAPTIVE IDENTIFICATION AND MODEL TRACKING BY A FLEXIBLE SPACECRAFT
J. M. SKOWRONSKI (Southern California, University, Los Angeles, CA; Queensland, University, Brisbane, Australia) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(AIAA PAPER 89-0541)

A rigid-flexible spacecraft structure subject to bounded uncertainty in structural parameters and payload, with large articulation angles, is modeled by a hybrid multidimensional system with high (untruncated) geometric nonlinearity and Coriolis forces. It is to be controlled adaptively to track a rigid body reference model with desired dynamics. To this aim, the system is replaced by a nonlinear adaptive, state and parameter identifier with considerably reduced number of DOF and made exactly integrable, i.e. with solutions in closed form. The technique allows for the tracking to occur with stipulated precision obtained in stipulated real time. The reduced dynamics and the exact integrability of the identifier and the adaptive laws make on-line computation of the algorithms simple enough to be made sufficiently fast on a small on-board computer. Author

A89-25437#
MODAL IDENTITIES FOR MULTIBODY ELASTIC SPACECRAFT - AN AID TO SELECTING MODES FOR SIMULATION
HARI B. HABLANI (Rockwell International Corp., Seal Beach, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 14 p. refs
(AIAA PAPER 89-0544)

This paper answers the question: which set of modes furnishes a higher fidelity math model of dynamics of a multibody, deformable spacecraft - the hinges-free or hinges-locked vehicle modes? Two sets of general, discretized, linear equations of motion of a spacecraft with an arbitrary number of deformable appendages, each articulated directly to the core body, are obtained using the above two families of modes. By comparing these equations, ten sets of modal identities are constructed which involve modal momenta coefficients and frequencies associated with both classes of modes. By applying the above identities to a four-body spacecraft, the hinges-locked vehicle modes are found to yield a higher fidelity model than hinges-free modes, because the latter modes have nonconverging modal coefficients. Author

A89-25613*# Florida Univ., Gainesville.
GLOBAL SENSITIVITY ANALYSIS IN CONTROL-AUGMENTED STRUCTURAL SYNTHESIS
CHRISTINA L. BLOEBAUM (Florida, University, Gainesville) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(Contract NAG1-688)
(AIAA PAPER 89-0844)

In this paper, an integrated approach to structural/control design is proposed in which variables in both the passive (structural) and active (control) disciplines of an optimization process are changed simultaneously. The global sensitivity equation (GSE) method of Sobieszczanski-Sobieski (1988) is used to obtain the behavior

sensitivity derivatives necessary for the linear approximations used in the parallel multidisciplinary synthesis problem. The GSE allows for the decoupling of large systems into smaller subsystems and thus makes it possible to determine the local sensitivities of each subsystem's outputs to its inputs and parameters. The advantages in using the GSE method are demonstrated using a finite-element representation of a truss structure equipped with active lateral displacement controllers, which is undergoing forced vibration. I.S.

A89-26192
ANALYTIC METHODS FOR THE MODELING OF FLEXIBLE STRUCTURES

J. M. SCHUMACHER (Stichting Mathematisch Centrum, Centrum voor Wiskunde en Informatica, Amsterdam, Netherlands) IN: Analysis and optimization of systems; Proceedings of the Eighth International Conference, Juan-les-Pins, France, June 8-10, 1988. Berlin and New York, Springer-Verlag, 1988, p. 461-471. refs

The modeling of structures built up by interconnecting a moderate number of distributed elements, each of which can be described by the classical equations of mathematical physics, is discussed. Techniques for operations on analytic matrices are considered which may be applied to obtain methods for specific computational goals. Three such methods for the computation of natural frequencies are examined. C.D.

A89-26292
NDT OF COMPOSITE STRUCTURES USED IN SPACE APPLICATIONS

THOMAS C. KOSHY (ISRO, Vikram Sarabhai Space Centre, Trivandrum, India) IN: Composite materials and structures; Proceedings of the International Conference, Madras, India, Jan. 6-9, 1988. New Delhi, Tata McGraw-Hill Publishing Co., Ltd., 1988, p. 417-423. refs

The nondestructive testing of composite structures used in space applications is discussed. Particular attention is given to visual testing, liquid penetrants, radiography, high-frequency ultrasonics, low-frequency ultrasonics, the Fokker bond tester, IR thermography, beta radiations, holography, and acoustic emission. It is found that, in some cases, it is necessary to use a combination of NDT techniques to successfully evaluate a composite structure. K.K.

A89-27175#
STRUCTURAL RELIABILITY IN AEROSPACE DESIGN

A. V. PATKI (ISRO, Satellite Centre, Bangalore, India) ESA Journal (ISSN 0379-2285), vol. 12, no. 3, 1988, p. 397-400.

The concept of a reliability figure is widely used in aerospace design. Though very common and well developed for electronics systems and components, it is not used directly for structural systems. This note attempts to show how reliability estimates can be incorporated in present aerospace design practice. A typical simple case is worked out to show the implicit reliability figures using these margins. Author

A89-27698#
LOCALIZATION OF VIBRATIONS IN LARGE SPACE REFLECTORS

ODDVAR O. BENDIKSEN (Princeton University, NJ) and PHILLIP J. CORNWELL (Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2B, p. 925-935) AIAA Journal (ISSN 0001-1452), vol. 27, Feb. 1989, p. 219-226. Previously cited in issue 14, p. 2117, Accession no. A87-33745. refs

A89-27699#
STRONG MODE LOCALIZATION IN NEARLY PERIODIC DISORDERED STRUCTURES

CHRISTOPHE PIERRE (Michigan, University, Ann Arbor) and PHILIP D. CHA AIAA Journal (ISSN 0001-1452), vol. 27, Feb. 1989, p. 227-241. Research supported by the University of Michigan. refs
(Contract NSF MSM-87-00820)

An investigation of the effects of disorder on the dynamics of nearly periodic structures is presented. Emphasis is placed on the study of mode localization and vibration-confinement phenomena for mistuned assemblies of coupled, multi-degree-of-freedom component systems. Perturbation methods are developed and applied to predict the occurrence of localized modes and analyze their characteristics. Strong localization is shown to occur for weak coupling between component systems. Furthermore, a 'modal' coupling parameter is defined that governs the possibility for localization in a given mode. Generally speaking, higher modes are shown to be more susceptible to localization than lower ones, and localization is unavoidable if the mode number is large enough. The occurrence of localization is also shown to be dependent upon the location of the coupling constraint between the component systems. Author

A89-28481
STRUCTURAL AND CONTROL OPTIMIZATION OF SPACE STRUCTURES

RAMANA V. GRANDHI (Wright State University, Dayton, OH) Computers and Structures (ISSN 0045-7949), vol. 31, no. 2, 1989, p. 139-150. Research supported by USAF. refs

A simultaneous structural and control optimization of flexible structures is presented in this paper. Behavior constraints are imposed on the closed-loop eigenvalue distribution and the damping parameters. Optimum results are obtained with three different optimization algorithms, and the nonunique nature of the optimum solutions is discussed. Also, the minimization of the Frobenious norm is investigated. A two-bar truss and an ACOSS four structure were designed and numerical comparisons are presented. The qualitative aspects of the optimum solutions are discussed with the transient response and control effort simulations. Author

A89-28500
ANALYSIS AND SIMULATION OF A CONTROLLED RIGID SPACECRAFT - STABILITY AND INSTABILITY NEAR ATTRACTORS

CHRISTOPHER I. BYRNES (Arizona State University, Tempe), SALVATORE MONACO (L'Aquila, Universita, Italy), ALBERTO ISIDORI (Roma I, Universita, Italy), and STORNELLI SABATINO (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 81-85. Research supported by USAF, NSF, MPI, and Telespazio S.p.A. refs

The authors give an analysis and simulation of the asymptotic properties of various closed-loop trajectories of the rigid-body model of a controlled spacecraft. Recent results are described which show that the rigid body for a spacecraft controlled by two independent pairs of gas jets is locally controllable but not locally asymptotically stabilizable about reference attitudes. The authors analyze, in the context of feedback stabilization about an attractor, the asymptotic properties of closed-loop trajectories when a feedback law driving the motion to a revolute cycle about a principal axis is implemented. Simulations support such convergence but indicate that convergence is quite slow, due to the fact that this cycle lies, as it must, on an invariant center manifold for this system. In particular, while the design is based on a nonlinear enhancement of root-locus theory, such attractors have no linear analogue. I.E.

A89-28634
REST-TO-REST SLEWING OF FLEXIBLE STRUCTURES IN MINIMUM TIME

ENRIQUE BARBIERI (Tulane University, New Orleans, LA) and UMIT OZGUNER (Ohio State University, Columbus) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1633-1638. refs

The rest-to-rest slewing of flexible structures in minimum time

is considered via phase-plane techniques. The trajectories are shown to exhibit a mirror-image symmetry in the phase plane. The advantage of this approach is that the switching control law can be expressed in terms of the rigid body states only, thereby resulting in a closed-loop strategy. Simulations are included for a one-bending model of a flexible slewing structure. I.E.

A89-28638
ROBUSTNESS OF FLEXIBLE STRUCTURES AGAINST SMALL TIME DELAYS
J. BONTSEMA and S. A. DE VRIES (Groningen, Rijksuniversiteit, Netherlands) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1647, 1648. Research supported by the Stichting voor de Technische Wetenschappen. refs

The authors give transfer matrices for some models described by partial differential equations. From these transfer matrices the poles and zeros are easily derived. The effect of a small time delay in the feedback loop is considered, and it is shown that if the feedthrough in the loop is too strong, this will give instability. The transfer matrices have the advantage that the amount of feedthrough is easily checked. I.E.

A89-28640
IDENTIFICATION OF FLEXIBLE STRUCTURES USING AN ADAPTIVE ORDER-RECURSIVE METHOD
FARYAR JABBARI (California, University, Irvine) and J. S. GIBSON (California, University, Los Angeles) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1668-1673. refs
(Contract AF-AFOSR-87-0373)

The authors present adaptive parameter identification results for a complex flexible structure with many closely packed natural frequencies. Least-squares lattice filters are used to estimate the number of excited modes, natural frequencies and damping ratios from input/output data. One-step-ahead output prediction also is generated by the lattice filters. I.E.

A89-28641* Brown Univ., Providence, RI.
SPATIAL VERSUS TIME HYSTERESIS IN DAMPING MECHANISMS
H. T. BANKS, R. H. FABIANO, Y. WANG (Brown University, Providence, RI), D. J. INMAN, and H. CUDNEY, JR. (New York, State University, Buffalo) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1674-1677. refs
(Contract NAG1-517; NGT-33-183-802; AF-AFOSR-84-0398; AF-AFOSR-85-0220; AF-AFOSR-85-0119; NSF MSM-83-51807; F49620-86-C-0111)

A description is given of continuing investigations on the task of estimating internal damping mechanisms in flexible structures. Specifically, two models for internal damping in Euler-Bernoulli beams are considered: spatial hysteresis and time hysteresis. A theoretically sound computational algorithm for estimation is described, and experimental results are discussed. It is concluded that both models perform well in the sense that they accurately predict response for the experiments conducted. I.E.

A89-28650
LINEARIZED MODELS FOR THE CONTROL OF ROTATING BEAMS
J. BAILLIEUL (Boston University, MA) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1726-1731. refs
(Contract AF-AFOSR-85-0144)

A geometrically exact dynamical model for the rotation of a planar rigid body with an elastic beam attachment is presented. This model is essentially nonlinear and involves a partial differential-integral equation. Consistent finite-dimensional approximations of the model are obtained in terms of the dynamics of carefully chosen kinematic chains in which the 1-DOF rotary joint motions are governed by idealized torsional springs. For purposes of local analysis or to support implementation of rotational control, the chain models can be linearized about equilibrium rotations. In the case of one particular body-beam system, it is shown that the linearized chain models provide consistent approximations to fourth-order partial differential equations. The form of these equations is crucially dependent on the underlying equilibrium rotation. I.E.

A89-28651
NONLINEAR DYNAMICS OF FLEXIBLE STRUCTURES - GEOMETRICALLY EXACT FORMULATION AND STABILITY
J. C. SIMO and T. A. POSBERGH (Stanford University, CA) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1732-1737. Research supported by USAF. refs

The stability of flexible structures coupled with rigid bodies performing large overall motions is investigated. The analysis is based on geometrically exact models which have no restriction on the degree of flexibility and satisfy of all invariance requirements under superposed rigid body motions. For these models there is a natural decomposition which decouples the dynamics into a space of rigid-body motions and its complement. The stability of relative equilibria are then explored by a method referred to as the energy-momentum method, which incorporates the conserved quantities of the system. By exploiting these invariants along with the underlying structure, stability criteria for the relative equilibria can be found. I.E.

A89-29200#
MOTION AND DEFORMATION OF VERY LARGE SPACE STRUCTURES
RAMESH B. MALLA (Connecticut, University, Storrs), WILLIAM A. NASH, and THOMAS J. LARDNER (Massachusetts, University, Amherst) AIAA Journal (ISSN 0001-1452), vol. 27, March 1989, p. 374-376.
(Contract AF-AFOSR-83-0025)

The equations of motion for a very large axially flexible structure orbiting the earth with planar motion in a general noncircular orbit are developed. The equations are used to study the effects of the orbit eccentricity on the motion and deformation of a large space structure under the action of the earth's gravitational forces. It is shown that an increase in orbit eccentricity disturbs the attitude motion of the space structure. Although the orbit eccentricity produces only small magnitude structural deformation, it is found that, for highly eccentric orbits, the structure may tumble continuously. R.B.

A89-30653*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
MULTIPLE BOUNDARY CONDITION TESTING ERROR ANALYSIS
R. J. GLASER, C. P. KUO, and B. K. WADA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 12-20. refs
(AIAA PAPER 89-1162)

Techniques for interpreting data from multiple-boundary-condition (MBC) ground tests of large space structures are developed analytically and demonstrated. The use of MBC testing to validate structures too large to stand alone on the ground is explained; the generalized least-squares mass and stiffness curve-fitting methods typically applied to MBC test data are reviewed; and a detailed error analysis is performed. Consideration is given to sensitivity coefficients, covariance-matrix theory, the correspondence between test and analysis modes, constraints and step sizes, convergence criteria, and factor-analysis theory. Numerical results for a simple beam problem are presented

in tables and briefly characterized. The improved error-updating capabilities of MBC testing are confirmed, and it is concluded that reasonably accurate results can be obtained using a diagonal covariance matrix. T.K.

A89-30661#
AN EXPERIMENTAL AND ANALYTICAL SYNTHESIS OF CONTROLLED STRUCTURE DESIGN
LEE D. PETERSON, JAMES J. ALLEN, JAMES P. LAUFFER, and A. KEITH MILLER (Sandia National Laboratories, Albuquerque, NM) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 91-103. refs
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 89-1170)

Recent research into the design and implementation of large controlled structures at Sandia National Laboratories is reviewed and illustrated with extensive drawings, diagrams, graphs, and photographs. The focus is on efforts to design a dynamic controller to maintain the shape and pointing accuracy of the Gamma Truss Structure test bed, a lightly damped polycarbonate-tube structure equipped with four sensors and four (noncollocated) actuators. Consideration is given to the development of the dynamic model, the derivation of the control theory, and synthesis algorithms for a suboptimal LQG controller based on a reduced-order model and an optimal-projection (OP) controller based on a 58th-order 'truth' model. The OP controller is found to give consistently better vibration control than the LQG controller, achieving 65-percent reduction without saturating the actuators. T.K.

A89-30671#
FORCED VIBRATIONS IN LARGE SPACE REFLECTORS WITH LOCALIZED MODES
ODDVAR O. BENDIKSEN (Princeton University, NJ) and PHILLIP J. CORNWELL IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 188-198. refs
(AIAA PAPER 89-1180)

The forced vibrational response of a large space reflector structure to (1) impulsive in-plane loading of one substructure or (2) out-of-plane displacement of a rigid member is investigated analytically, considering perfect and imperfect reflectors with 18 radial ribs and subject to both localized and extended modes. The approach of Cornwell and Bendiksen (1987) is extended to multi-DOF substructures. Numerical results are presented in extensive graphs and discussed in detail. In case (1), it is demonstrated that the disturbance does not propagate throughout the structure if the first mode group (primarily the first bending mode) is localized. In case (2), the motion of the ribs in an imperfect structure is found to have variable amplitude. T.K.

A89-30684*# CSA Engineering, Inc., Palo Alto, CA.
VERY LOW FREQUENCY SUSPENSION SYSTEMS FOR DYNAMIC TESTING
DAVID A. KIENHOLZ (CSA Engineering, Inc., Palo Alto, CA), EDWARD F. CRAWLEY (MIT, Cambridge, MA), and T. JEFFREY HARVEY (AEC-Able Engineering, Inc., Goleta, CA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 327-336. Research supported by NASA and Lockheed Missiles and Space Co., Inc.
(AIAA PAPER 89-1194)

Specifications for a Space Station suspension system which can provide rigid-body translation frequencies on the order of 0.1-0.2 Hz for a 50-foot payload weighing about 3400 lb and having a number of highly flexible appendages are discussed. Two suspension devices are considered, an all-mechanical passive device based on coil springs and a device using a combination of a passive pneumatic system and an active electromagnetic system. Test results show that both devices meet the initial requirements. R.R.

A89-30691#
NONLINEAR FINITE ELEMENT SIMULATION OF THE LARGE ANGLE MOTION OF FLEXIBLE BODIES
LEE D. PETERSON (Sandia National Laboratories, Albuquerque, NM) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 396-404. refs
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 89-1201)

A nonlinear large-strain-displacement structural finite element program is used to simulate the large-angle motions of flexible bodies. Results are presented for three examples: (1) a large-angle maneuver of a cantilevered flexible robot arm; (2) the nutation of a rotating free-free beam observed from a rotating frame; and (3) the spin-up of a cantilevered beam from rest. The spin-up problem is used to test for the false divergence of the beam above a critical spin rate. R.R.

A89-30692#
NON-LINEAR STRAIN-DISPLACEMENT RELATIONS AND FLEXIBLE MULTIBODY DYNAMICS
A. H. VON FLOTOW (MIT, Cambridge, MA) and C. E. PADILLA IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 405-413. refs
(AIAA PAPER 89-1202)

The dynamics of chains of flexible bodies undergoing large rigid body motions and small elastic deflections is investigated, with emphasis on the role of nonlinear strain-displacement relations in the development of the motion equations for the deflections of these systems. Numerical results are presented for a two-link chain constrained to move in the plane and subject to hinge torques. Slew maneuver simulations have been performed for models with and without properly modeled kinetics of deformation. R.R.

A89-30701#
THE FRACTIONAL ORDER STATE EQUATIONS FOR THE CONTROL OF VISCOELASTICALLY DAMPED STRUCTURES
R. L. BAGLEY and R. A. CALICO (USAF, Institute of Technology, Wright-Patterson AFB, OH) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 487-496. refs
(AIAA PAPER 89-1213)

The fractional order state equations are developed to predict the effects of feedback intended to reduce motion in damped structures. The mechanical properties of damping materials are modeled using fractional order time derivatives of stress and strain. These models accurately describe the broad-band effects of material damping in the structure's equations of motion. The resulting structural equations of motion are used to derive the fractional order state equations. Substantial differences between the structural and state equations are seen to exist. The mathematical form of the state equations suggests the feedback of fractional order time derivatives of structural displacements to improve control system performance. Several other advantages of the fractional order state formulation are discussed. Author

A89-30724#
MASS CONSERVATION IN THE IDENTIFICATION OF SPACE STRUCTURES
MENAHEM BARUCH (Virginia Polytechnic Institute and State University, Blacksburg) and YORAM ZEMEL IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics

and Astronautics, 1989, p. 710-712. refs
(AIAA PAPER 89-1239)

In the identification process of space structures it is extremely important to keep the rigid body characteristics of the structure uncorrupted. The Methods of Reference Basis (MRB) achieve this by using a Law of Mass Conservation. In line with the law a proper definition for isolation of the measured elastic modes from rigid body movements is also introduced. Author

A89-30725#
LOCATION OF MODELING ERRORS USING MODAL TEST DATA
CHENG S. LIN (Aerospace Corp., El Segundo, CA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 713-720. refs
(AIAA PAPER 89-1240)

A unity check method is proposed to locate the physical positions of modeling errors in stiffness using modal test data. The method uses the cross unity check between a flexibility matrix derived from modal test data and the analytical stiffness matrix to locate the errors; it cannot determine the changes needed to correct the errors. Effectiveness of the method is demonstrated through numerical examples both with stiffness matrix unreduced and stiffness reduced by Guyan reduction. Sensitivity of the method to lack of orthogonality in measured modes is discussed. Note that the flexibility matrix can also be derived from static test data instead of modal test data. Author

A89-30726*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ON THE STATE ESTIMATION OF STRUCTURES WITH SECOND ORDER OBSERVERS
W. KEITH BELVIN (NASA, Langley Research Center, Hampton, VA) and K. C. PARK (Colorado, University, Boulder) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 721-727. refs
(Contract F49620-87-C-0074)
(AIAA PAPER 89-1241)

The use of the linear quadratic regulator control synthesis techniques implies the availability of full state feedback. For vibration control of structures, usually only a limited number of states are measured from which an observer model reconstructs the full state. This paper shows that using second-order observers is a viable technique for reconstructing the unmeasured states of structures under mildly restrictive conditions. Moreover, the computational advantages of the second-order observer, as compared to a first-order observer, indicate that significantly larger observer models may be utilized. Numerical examples are used to demonstrate the performance of second-order observers. The implications of second-order observers in the development of the control/structures interaction technology is discussed. Author

A89-30727#
AUTOMATING THE IDENTIFICATION OF STRUCTURAL MODEL PARAMETERS
JAMES J. ALLEN and DAVID R. MARTINEZ (Sandia National Laboratories, Albuquerque, NM) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 728-736. refs
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 89-1242)

An implementation of a tool for the system identification of large structural model based on the integration of commercial software packages is presented. The method integrates commercial software for finite element modeling (MSC/NASTRAN), mathematical programming techniques (ADS), and general linear system analysis (PRO-MATLAB). The use of the automated parameter identification software is illustrated for the following two applications: estimation of the material constants and support stiffness of a truss structure and estimation of the stiffness and mass properties of an electronics package. V.L.

A89-30737*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FREE-VIBRATION CHARACTERISTICS AND CORRELATION OF A SPACE STATION SPLIT-BLANKET SOLAR ARRAY
KELLY S. CARNEY and FRANCIS J. SHAKER (NASA, Lewis Research Center, Cleveland, OH) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 813-819. Previously announced in STAR as N89-15438. refs
(AIAA PAPER 89-1252)

Two methods for studying the free-vibration characteristics of a large split-blanket solar array in a zero-g cantilevered configuration are presented. The zero-g configuration corresponds to an on-orbit configuration of the Space Station solar array. The first method applies the equations of continuum mechanics to determine the natural frequencies of the array; the second uses the finite element method program, MSC/NASTRAN. The stiffness matrix from the NASTRAN solution was found to be erroneously grounded. The results from the two methods are compared. It is concluded that the grounding does not seriously compromise the solution to the elastic modes of the solar array. However, the correct rigid body modes need to be icluded to obtain the correct dynamic model. Author

A89-30743#
EXACT STATIC AND DYNAMIC STIFFNESS MATRICES FOR GENERAL VARIABLE CROSS SECTION MEMBERS
MOSHE EISENBERGER (Carnegie-Mellon University, Pittsburgh, PA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 852-858. refs
(AIAA PAPER 89-1258)

This paper concerns the formulation of a new finite element method for the solution of beams with variable cross section. Using only one element it is possible to derive the exact static and dynamic stiffness matrices (up to the accuracy of the computer), for any polynomial variation of axial, torsional, and bending stiffnesses along the beam. Examples are given for the accuracy and efficiency of the method. Author

A89-30763*# Lockheed Engineering and Sciences Co., Houston, TX.
DYNAMIC ANALYSIS OF THE SPACE STATION TRUSS STRUCTURE BASED ON A CONTINUUM REPRESENTATION
SEGUN THOMAS (Lockheed Engineering and Sciences, Houston, TX) and NORRIS STUBBS (Texas A & M University, College Station) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1062-1068. refs
(Contract NAS9-17900)
(AIAA PAPER 89-1280)

A mathematical model is developed for the real-time simulation of a Space Station. First, a continuum equivalent representation of the Space Station truss structure is presented which accounts for extensional, transverse, and shear deformations and coupling between them. The procedure achieves a significant reduction in the degrees of freedom of the system. Dynamic equations are then formulated for the continuum equivalent of the Space Station truss structure based on the matrix version of Kane's dynamical equations. Finally, constraint equations are derived for the dynamic analysis of flexible bodies with closed loop configuration. V.L.

A89-30770#
VIBRATION CHARACTERISTICS AND SHAPE CONTROL OF ADAPTIVE PLANAR TRUSS STRUCTURES
FUMIHIRO KUWAO, MAKOTO YOSHIHARA, SHOICHI MOTOHASHI, KENICHI TAKAHARA (Toshiba Corp., Kawasaki, Japan), and MICHIHIRO NATORI (Tokyo, University, Sagamihara, Japan) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1136-1144. refs
(AIAA PAPER 89-1288)

The vibration characteristics of a planar truss structure are evaluated by conducting a modal survey of the function model and analyzing the mathematical model. The effectiveness of shape control for the compensation of the deformation due to the gravity force is demonstrated. The implications of the results for the adaptive planar truss structures of large space antennas are briefly discussed. V.L.

A89-30772*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SYSTEM IDENTIFICATION TEST USING ACTIVE MEMBERS
JAY-CHUNG CHEN and JAMES L. FANSON (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1154-1163. refs
(AIAA PAPER 89-1290)

A modal test using active members as the excitation source has been performed on the Precision Truss. Using the step sine testing technique, the frequency response functions are obtained and the modal parameters are extracted by the curve-fitting method. Total of 10 global modes and 3 local modes are obtained. The results are compared with those obtained by the conventional external excitation test. Author

A89-30787#
DYNAMICS OF COMPLEX TRUSS-TYPE SPACE STRUCTURES
Y. YONG and Y. K. LIN (Florida Atlantic University, Boca Raton) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1295-1304. refs
(Contract AF-AFOSR-88-005)
(AIAA PAPER 89-1307)

A mathematical procedure developed for the analysis of damped periodic and piecewise periodic structures is extended to more complicated configurations of intersecting arrays. The proposed procedure is a hybrid of finite element, transfer matrix, and wave propagation approaches, with a finite element formulation used to model a periodic truss unit or each type of periodic truss unit in the structure so that the dynamic characteristics of such a unit can be represented as accurately as desired, regardless of its complexity. Traditional transfer matrices for state vectors are transformed to transfer matrices for wave vectors, so that various waves propagating along the structure in different directions can be identified and certain numerical difficulties can be circumvented. An example is given to illustrate the application of the method. V.L.

A89-30792#
INTEGRATED DIRECT OPTIMIZATION OF STRUCTURE/REGULATOR/OBSERVER FOR LARGE FLEXIBLE SPACECRAFT
JUNJIRO ONODA and NAOYUKI WATANABE (Tokyo, University, Sagamihara, Japan) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1336-1344. refs
(AIAA PAPER 89-1313)

An numerical direct approach to design an optimal controller composed of regulator and observer has been proposed for integrated structure/controller optimization of flexible spacecraft. The approach takes account of uncontrolled residual modes. Therefore, it does not only optimize based on an actual performance index degraded by the residual modes but also suppresses the spillover instability. The approach has been applied to a simply supported beam examples first, and the characteristics of the resulting system have been investigated. The examples have demonstrated that the resulting controller is stable even when LQG controller is unstable. Insensitivity of the resulting system to parameter variations is also demonstrated compared with LQG controller. Subsequently, the approach has been incorporated in a structure/controller simultaneous optimization scheme. The practicality and effectiveness of the present scheme has been demonstrated in a beam-like flexible spacecraft example. Author

A89-30804*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
EXPERIMENTAL STUDIES OF ADAPTIVE STRUCTURES FOR PRECISION PERFORMANCE
G.-S. CHEN, B. J. LURIE, and B. K. WADA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1462-1472. refs
(AIAA PAPER 89-1327)

An experimental study was made of the adaptive structure concept. Experimental data were obtained for a three-longeron, thirteen-bay truss-type test structure. This test structure can be softly suspended as well as rigidly clamped at the central bay. The load-carrying active member consists of a stack of concentric piezoelectric wafers, an eddy current displacement sensor, and a strain gage force sensor. A bridge (or compound) feedback technique developed in communication engineering is applied to the problem of active damping augmentation in adaptive structures. Using collocated force and velocity feedback around the active member, a desired output mechanical impedance can be implemented to maximize energy absorption by the active members. In addition, large gains can be implemented to linearize the active member's nonlinear behavior. Good agreements with linear finite element analysis was found for both static and dynamic structural responses. An 11 percent damping in the first bending mode was demonstrated in the closed-loop damping experiment. Author

A89-30805#
DYNAMICS AND CONTROL OF A SPATIAL ACTIVE TRUSS ACTUATOR
H. H. ROBERTSHAW, R. H. WYNN, JR., H. F. KUNG, S. L. HENDRICKS, and W. W. CLARK (Virginia Polytechnic Institute and State University, Blacksburg) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1473-1479. refs
(AIAA PAPER 89-1328)

The methods and the results of an analytical study of the vibration reduction potential of an octahedral, three degree-of-freedom, spatial active truss are presented. The continuum controlled was a 1/4-inch brass rod 75 inches long, intrumented with strain gages to transduce strain. The active truss had extensible links with machine screws driven by dc motors. Good vibration control was achieved with good agreement between the experiment and the analysis. Author

A89-30814*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MODEL REDUCTION FOR FLEXIBLE SPACE STRUCTURES
WODEK GAWRONSKI and TREVOR WILLIAMS (NASA, Langley Research Center, Hampton, VA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers.

Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1555-1565. refs
(AIAA PAPER 89-1339)

This paper presents the conditions under which modal truncation yields a near-optimal reduced-order model for a flexible structure. Next, a robust model reduction technique to cope with the damping uncertainties typical of flexible space structure is developed. Finally, a flexible truss and the COFS-1 structure are used to give realistic applications for the model reduction techniques studied in the paper. Author

A89-30815*# Lockheed Missiles and Space Co., Sunnyvale, CA.
DESIGN, ANALYSIS, AND TESTING OF A HYBRID SCALE STRUCTURAL DYNAMIC MODEL OF A SPACE STATION
MARC J. GRONET (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA), EDWARD F. CRAWLEY (MIT, Cambridge, MA), and BRADLEY R. ALLEN (CSA Engineering, Inc., Palo Alto, CA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1567-1575. Research supported by NASA. refs
(AIAA PAPER 89-1340)

The impracticality of testing the fully-assembled on-orbit configurations of future large erectable space platforms fosters an increased reliance on other means for verifying predicted structural dynamic performance. One option is scale modeling. This paper discusses the design of a hybrid scale dynamic test model of the Freedom Space Station and its associated suspension system. Hybrid scaling laws are reviewed, followed by scale factor trades, component design examples, and an analytical evaluation of the overall model fidelity. Component and subassembly test results from a six-bay hybrid scale model truss are presented. Potential interactions of gravity and the suspension system with the free-free dynamics of the scale model are investigated. Suspension system design parameters, such as the number, location, mass, and stiffness of the suspension devices are traded to minimize undesirable interactions and form the basis for an overall suspension system concept for the scale model. Author

A89-30819*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
PRACTICES IN ADEQUATE STRUCTURAL DESIGN
ROBERT S. RYAN (NASA, Marshall Space Flight Center, Huntsville, AL) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1612-1622. refs
(AIAA PAPER 89-1344)

An account is given of the guidelines for safe and reliable space vehicle design, especially in the structural engineering area, which have been formulated by NASA in the aftermath of the Space Shuttle Challenger accident in 1986. Illustrative examples are presented from state-of-the-art, performance-driven hardware whose design ineluctably gives rise to a high sensitivity to small variations and uncertainties. It is recommended that such hardware be designed with a view to easy inspectability and manufacturability, with emphasis on the role played in system structures by fracture mechanics. Static and dynamic coupling effects must be precluded wherever possible. O.C.

A89-30838#
LARGE DEFLECTION STATIC AND DYNAMIC FINITE ELEMENT ANALYSES OF COMPOSITE BEAMS WITH ARBITRARY CROSS-SECTIONAL WARPING
ALAN D. STEMPLE and SUNG W. LEE (Maryland, University, College Park) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1788-1798. refs
(Contract DAAL03-88-C-002)
(AIAA PAPER 89-1363)

A beam finite-element formulation that properly takes into account the warping effects of composite beams undergoing large deflection has been developed. This formulation can be used for static and free vibration analysis of both rotating and nonrotating composite beams. A comparative study with a solid-element model is presented as well as correlation with experimental observations. The present approach allows the modeling of thin-walled composite beams with complicated cross-section, tapers, and arbitrary planforms. Correlation of numerical tests with a three-dimensional solid-element formulation and experimental results demonstrate the validity and effectiveness of the present approach. Author

A89-30854*# Massachusetts Inst. of Tech., Cambridge.
A FREQUENCY DOMAIN ANALYSIS FOR DAMPED SPACE STRUCTURES
NESBITT W. HAGOOD and EDWARD F. CRAWLEY (MIT, Cambridge, MA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1936-1946. refs
(Contract NAGW-21)
(AIAA PAPER 89-1381)

A method is presented for the analysis of damped structural systems in which the structural components are represented by impedance models and analyzed in the frequency domain. Methods are presented to assemble and condense system impedance matrices, and then to identify approximate mass, stiffness, and damping matrices for systems whose impedances are complicated functions of frequency. Formulas are derived for determination of approximate values for system natural frequencies and damping using frequency domain quantities. The sensitivities of these approximate values to system parameter changes are analyzed. The implementation of these analysis tools is discussed and applied to a simple mechanical system. Author

A89-30855#
MODEL CORRECTION USING A SYMMETRIC EIGENSTRUCTURE ASSIGNMENT TECHNIQUE
D. C. ZIMMERMANN (Florida, University, Gainesville) and M. WIDENGREN (Kungliga Tekniska Hogskolan, Stockholm, Sweden) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1947-1954. refs
(AIAA PAPER 89-1382)

Improvement of structural models by incorporating measured structural modal parameters is approached from a controls aspect. The approach is developed for linear structures which exhibit nonproportional damping. Residual damping and stiffness matrices are determined such that the improved analytical model eigenstructure matches that obtained experimentally. The method is based on the development of a symmetric eigenstructure assignment algorithm. Examples will be presented which demonstrate the algorithm. Author

A89-30856#
DYNAMIC CONTINUUM MODELING OF BEAMLIKE SPACE STRUCTURES USING FINITE ELEMENT MATRICES
USIK LEE (Korea Institute of Aeronautical Technology, Seoul, Republic of Korea) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1955-1962. refs
(AIAA PAPER 89-1383)

A rational and straightforward method is introduced for developing equivalent continuum models of large beam-like periodic lattice structures based on energy equivalence. Extended Timoshenko beam model is chosen to take account of the effects

due to couplings between extension, transverse shear and bending deformations. The procedure for developing continuum models involves utilizing well-defined existing finite element matrices directly in calculating strain and kinetic energies from which equivalent continuum structural and dynamic properties are induced. The numerical results of free vibration analysis show that the method developed in this paper gives very reliable dynamic characteristics compared to other methods. Author

A89-30866*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EFFICIENT EIGENVALUE ASSIGNMENT FOR LARGE SPACE STRUCTURES
PEIMAN G. MAGHAMI and JER-NAN JUANG (NASA, Langley Research Center, Hampton, VA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 2037-2045. refs
(AIAA PAPER 89-1393)

A novel and efficient approach for the eigenvalue assignment of large first-order time-invariant systems is developed using full-state feedback and output feedback. First, a Schur decomposition is applied to triangularize the state matrix. Second, a series of coordinate rotations (Givens rotations) are used to move the eigenvalue to be reassigned to the end of the diagonal of its Schur form. Third, the eigenvalue is moved to the desired location by a full-state feedback, without affecting the remaining eigenvalues. The second and third step can be repeated until all the assignable eigenvalues are moved to the desired locations. Given the freedom of multiple inputs, the feedback gain matrix is calculated to minimize an objective function composed of a gain matrix norm and/or a robustness index of the closed-loop system. Numerical examples are given to demonstrate the feasibility of the proposed approach. Author

A89-30884*# Alabama Univ., Huntsville.
DESIGN OF A SECONDARY DEBRIS CONTAINMENT SHIELD FOR LARGE SPACE STRUCTURES
WILLIAM P. SCHONBERG (Alabama, University, Huntsville) and ROY A. TAYLOR (NASA, Marshall Space Flight Center, Huntsville, AL) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 2193-2198. refs
(AIAA PAPER 89-1412)

All long-duration spacecraft are susceptible to impacts by meteoroids and pieces of orbiting space debris. Such impacts are expected to occur at extremely high speeds and can damage internal and external flight-critical systems of spacecraft. An effective mechanism is developed to protect external spacecraft subsystems against damage by ricochet particles formed during such impacts. Equations and design procedures for protective shield panels are developed based on observed ricochet phenomena and calculated ricochet particle sizes and speeds. Panel dimensions are shown to be strongly dependent on their inclination and on their distribution around a spacecraft module. It is concluded that obliquity effects of high-speed impacts must be considered in the design of any structure exposed to the meteoroid and space debris environment. Author

A89-30893*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
LOCATING DAMAGED MEMBERS IN A TRUSS STRUCTURE USING MODAL TEST DATA - A DEMONSTRATION EXPERIMENT
SUZANNE WEAVER SMITH (Virginia Polytechnic Institute and State University, Blacksburg) and PAUL E. MCGOWAN (NASA, Langley Research Center, Hampton, VA) AIAA, ASME, ASCE, AHS, and ASC, Srtuctures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989. 8 p. refs
(AIAA PAPER 89-1291)

An experiment is designed to demonstrate and verify the performance of the on-orbit assessment approach for large flexible space truss structures. The on-orbit assessment approach can be accomplished, in principle, with dynamic response information, structural identification methods, and model correlation techniques which produce an adjusted mathematical model. An optimal update of the structure model is formed using the response data, then examined to locate damaged members. The experiment uses a laboratory scale model truss structure which exhibits characteristics expected for large space truss structures. Vibration experiments are performed to generate response data for the damaged truss. The damage location approach is described, as well as analytical work performed in support of the vibration tests, the measured response of the test article, and some preliminary results. S.A.V.

A89-31091#
CONTROL OF ARTICULATED AND DEFORMABLE SPACE STRUCTURES
HAROLD L. ALEXANDER (Stanford University, CA) IN: Machine intelligence and autonomy for aerospace systems. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 327-347. refs

The technology developed to date for dynamic control of deformable space structures and articulated space robots is discussed with a view to applications associated with future space industrialization. A freely-floating manipulator base, such as a satellite robot, has no conveniently constant relationship between joint angles and end-effector position, relative to a target object. Noncollocated tip-position control has demonstrated benefits for the dynamic control of manipulators. Operational-space control, based on a full, nonlinear, rigid-body dynamic and kinematic model of the manipulator being controlled, is an additional possible method. Attention is given to laboratory simulations of several control systems. O.C.

A89-31525
VACUUM STRESSING TECHNIQUE FOR COMPOSITE LAMINATES INSPECTION BY OPTICAL METHOD
N. A. RUBAYI and S. H. LIEW (Southern Illinois University, Carbondale, IL) Experimental Techniques (ISSN 0732-8818), vol. 13, March 1989, p. 17-20. Research sponsored by the Southern Illinois University.

The application of the vacuum-stressing method is discussed as a nondestructive testing tool employed in conjunction with holographic interferometry for the detection of flaws and delaminations on or near the surface of composite laminates. Several eight-ply graphite/epoxy composite rectangular laminates were tested having unidirectional, cross-ply, and multiple-direction ply stacking sequences. The flaws made in the specimens were of either rectangular, equilateral, triangular, or circular shape. The effect of the shape, size, and location of the flaws on their detection and resulting fringe patterns was studied. The effect of the stacking sequence and ply orientation on flaw detection was also investigated. Three real-time holograms give representative results of the vacuum-stressing technique. S.A.V.

A89-31919*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THERMAL-STRESS-FREE FASTENERS FOR JOINING ORTHOTROPIC MATERIALS
MAX L. BLOSSER (NASA, Langley Research Center, Hampton, VA) AIAA Journal (ISSN 0001-1452), vol. 27, April 1989, p. 472-478. Previously cited in issue 19, p. 3036, Accession no. A87-44836. refs

N89-10297*# North Carolina Agricultural and Technical State Univ., Greensboro. Dept. of Architectural Engineering.
DYNAMICS AND CONTROL OF THE ORBITING GRID STRUCTURES AND THE SYNCHRONOUSLY DEPLOYABLE BEAM Final Report
ELIAS G. ABU-SABA 28 Sep. 1988 62 p
(Contract NAG1-405)
(NASA-CR-183205; NAS 1.26:183205) Avail: NTIS HC A04/MF A01 CSCL 20K

Analytical models were provided for the orbiting grid structure and the joint dominated beam and computational procedures used in determining the eigen value characteristics. Author

N89-10838*# Joint Inst. for Advancement of Flight Sciences, Washington, DC.
PROGRAM OF RESEARCH IN STRUCTURES AND DYNAMICS Final Report
Sep. 1988 35 p
(Contract NGR-09-010-078)
(NASA-CR-183191; NAS 1.26:183191) Avail: NTIS HC A03/MF A01 CSCL 01B

The Structures and Dynamics Program was first initiated in 1972 with the following two major objectives: to provide a basic understanding and working knowledge of some key areas pertinent to structures, solid mechanics, and dynamics technology including computer aided design; and to provide a comprehensive educational and research program at the NASA Langley Research Center leading to advanced degrees in the structures and dynamics areas. During the operation of the program the research work was done in support of the activities of both the Structures and Dynamics Division and the Loads and Aeroelasticity Division. During the period of 1972 to 1986 the Program provided support for two full-time faculty members, one part-time faculty member, three postdoctoral fellows, one research engineer, eight programmers, and 28 graduate research assistants. The faculty and staff of the program have published 144 papers and reports, and made 70 presentations at national and international meetings, describing their research findings. In addition, they organized and helped in the organization of 10 workshops and national symposia in the structures and dynamics areas. The graduate research assistants and the students enrolled in the program have written 20 masters theses and 2 doctoral dissertations. The overall progress is summarized. Author

N89-10914*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
UTILIZATION OF SPRAY ON FOAM INSULATION FOR MANNED AND UNMANNED SPACECRAFT AND STRUCTURES
THOMAS M. HANCOCK, III *In its* The 1988 Get Away Special Experimenter's Symposium p 81 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 22B

The idea of using spray-on foam insulation as a passive thermal and micrometeorite protection system is explored. The benefits of applying an exterior coating of foam insulation can be: (1) the foam can provide a thermally stable shield that can assist in reducing the strain on traditional space radiator systems and can also act as a passive thermal guard, allowing a greater fault tolerance if the standard system should fail; (2) the foam can act as an ablative shell diminishing the effects of natural and manmade debris striking the structure; (3) the foam is lightweight - about 1/2 ounce per sq ft; (4) the foam is low cost and easy to maintain; and (5) the foam is a stable material that does not react when exposed to earth or lunar environments. Author

N89-10936*# General Dynamics Corp., San Diego, CA. Space Systems Div.
DEVELOPMENT OF A VERIFICATION PROGRAM FOR DEPLOYABLE TRUSS ADVANCED TECHNOLOGY Final Report
JACK E. DYER Sep. 1988 161 p
(Contract NAS1-18274)
(NASA-CR-181703; NAS 1.26:181703) Avail: NTIS HC A08/MF A01 CSCL 22B

Use of large deployable space structures to satisfy the growth demands of space systems is contingent upon reducing the associated risks that pervade many related technical disciplines. The overall objectives of this program was to develop a detailed plan to verify deployable truss advanced technology applicable to future large space structures and to develop a preliminary design of a deployable truss reflector/beam structure for use a a technology demonstration test article. The planning is based on a Shuttle flight experiment program using deployable 5 and 15 meter aperture tetrahedral truss reflections and a 20 m long deployable truss beam structure. The plan addresses validation of analytical methods, the degree to which ground testing adequately simulates flight and in-space testing requirements for large precision antenna designs. Based on an assessment of future NASA and DOD space system requirements, the program was developed to verify four critical technology areas: deployment, shape accuracy and control, pointing and alignment, and articulation and maneuvers. The flight experiment technology verification objectives can be met using two shuttle flights with the total experiment integrated on a single Shuttle Test Experiment Platform (STEP) and a Mission Peculiar Experiment Support Structure (MPESS). First flight of the experiment can be achieved 60 months after go-ahead with a total program duration of 90 months. Author

N89-11250# Toronto Univ. (Ontario). Inst. for Aerospace Studies.
THE MINI-OSCILLATOR TECHNIQUE: A FINITE ELEMENT METHOD FOR THE MODELING OF LINEAR VISCOELASTIC STRUCTURES Thesis
DONALD J. MCTAVISH Mar. 1988 123 p
(UTIAS-323; ISSN-0082-5255) Avail: NTIS HC A06/MF A01

The use of finite elements to model complex structures has been traditionally effective with regard to mass properties and equilibrium elastic stiffness properties. A practical formulation is presented for the analysis of structures whose constituent materials may be classed as linear viscoelastic. Construction of viscoelastic finite element matrices fully compatible with the usual second order equations of motion is demonstrated, given a knowledge of material properties. The viscoelastic material properties are represented in the Laplace domain by the Golla-Hughes-McTavish (GHM) Analytic Model. The Mini-Oscillator Technique is introduced and developed through the consideration of a single modulus finite element for which the mass and elastic stiffness matrices are known. The simplest case of a single degree of freedom finite element is examined in detail to expose a mechanical analogy from which the mini oscillator technique derives its name. The procedure is then extended to the case of a general structural model with many elements. Each finite element may be of a different material with stiffness properties ranging between simple elastic and multi modulus viscoelastic. Author

N89-11793*# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
CONTROL OF FLEXIBLE STRUCTURES-2 (COFS-2) FLIGHT CONTROL, STRUCTURE AND GIMBAL SYSTEM INTERACTION STUDY Final Report
STANLEY FAY, STEPHEN GATES, TIMOTHY HENDERSON, LESTER SACKETT, KIM KIRCHWEY, ISAAC STODDARD, and JOEL STORCH Sep. 1988 205 p
(Contract NAS9-17560)
(NASA-CR-172095; R-2088; NAS 1.26:172095) Avail: NTIS HC A10/MF A01 CSCL 22/2

The second Control Of Flexible Structures Flight Experiment (COFS-2) includes a long mast as in the first flight experiment, but with the Langley 15-m hoop column antenna attached via a gimbal system to the top of the mast. The mast is to be mounted in the Space Shuttle cargo bay. The servo-driven gimbal system could be used to point the antenna relative to the mast. The dynamic interaction of the Shuttle Orbiter/COFS-2 system with the Orbiter on-orbit Flight Control System (FCS) and the gimbal pointing control system has been studied using analysis and simulation. The Orbiter pointing requirements have been assessed for their impact on allowable free drift time for COFS experiments. Three fixed antenna configurations were investigated. Also simulated was Orbiter attitude control behavior with active vernier jets during antenna slewing. The effect of experiment mast dampers was included. Control system stability and performance and loads on various portions of the COFS-2 structure were investigated. The study indicates possible undesirable interaction between the Orbiter FCS and the flexible, articulated COFS-2 mast/antenna system, even when restricted to vernier reaction jets. Author

N89-11794# CSA Engineering, Inc., Palo Alto, CA.
SCALING OF LARGE SPACE STRUCTURE JOINTS Final Report, Jul. 1987 - Feb. 1988
DAVID A. KIENHOLZ Jun. 1988 30 p
(Contract F33615-87-C-3239)
(AD-A197027; CSA-880204; AFWAL-TR-88-3047) Avail: NTIS HC A03/MF A01 CSCL 22/5

Large orbiting spacecraft will often use trusses as primary, load-carrying structure. Favorable strength/weight and stiffness/weight ratios as well as compact stowage make trusses a natural candidate for erectable space structures. However the sheer size of proposed spacecraft raises important questions with respect to verification of their predicted dynamic properties. Assembled orbiting structures will be, in many cases, much too large for ground vibration testing. Some are not even capable of supporting their own weight in the earth's gravity. Various truss structures currently proposed for on-orbit assembly are too large to be tested on the ground. This has led to renewed interest in scale models for verification of predicted structural dynamic properties. However, a realistic scale model truss requires joints whose stiffness and damping properties are in-scale with those of the full-size counterpart. The primary conclusion is that accurate scale modeling of erectable trusses is quite feasible. GRA

N89-12624*# Yale Univ., New Haven, CT. Center for Systems Science.
VIBRATION SUPPRESSION IN A LARGE SPACE STRUCTURE Final Report
KUMPATI S. NARENDRA Aug. 1988 12 p
(Contract NAS9-17395)
(NASA-CR-182831; NAS 1.26:182831) Avail: NTIS HC A03/MF A01 CSCL 22/2

The Yale University Center for Systems Science and the NASA Johnson Space Center collaborated in a study of vibration suppression in a large space structure during the period January 1985 to August 1987. The research proposal submitted by the Center to NASA concerned disturbance isolation in flexible space structures. The general objective of the proposal was to create within the Center a critical mass of expertise on problems related to the dynamics and control of large flexible space structures. A specific objective was to formulate both passive and active control strategies for the disturbance isolation problem. Both objectives were achieved during the period of the contract. While an extensive literature exists on the control of flexible space structures, it is generally acknowledged that many important questions remain open at even a fundamental level. Hence, instead of studying grossly simplified models of complex structural systems, it was decided as a first step to confine attention to detailed and thorough analyses of simple structures. Author

N89-12786* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TRUSS-CORE CORRUGATION FOR COMPRESSIVE LOADS Patent
RANDALL C. DAVIS, inventor (to NASA) and ROBERT JACKSON, inventor (to NASA) 13 Sep. 1988 9 p Filed 5 Mar. 1987
Supersedes N87-25496 (25 - 19, p 2601)
(NASA-CASE-LAR-13438-1; US-PATENT-4,769,968; US-PATENT-APPL-SN-022298; US-PATENT-CLASS-52-814; US-PATENT-CLASS-52-821; US-PATENT-CLASS-428-182)
Avail: US Patent and Trademark Office CSCL 13/2

A corrugated panel structure for supporting compressive loads is described which includes curved cap strips separated by truss-core web segments. The truss-core web segments are formed from first and second flat panels with a corrugated filler in between them. The corrugated filler extends in the direction of the compressive load. As a result, all components of the panel structure have a compressive load carrying capability resulting in a high strength-to-weight ratio when the compressive load is limiting. Application to rocket and aircraft structures is suggested.
Official Gazette of the U.S. Patent and Trademark Office

N89-13460*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PROCEEDINGS OF THE 4TH ANNUAL SCOLE WORKSHOP
LAWRENCE W. TAYLOR, JR., comp. Oct. 1988 383 p
Workshop held in Colorado Springs, Colo., 16 Nov. 1987
(NASA-TM-101503; NAS 1.15:101503) Avail: NTIS HC A17/MF A01 CSCL 22/2

This publication is a collection of papers presented at the Fourth Annual Spacecraft Control Laboratory Experiment (SCOLE) Workshop held at the U.S.A.F. Academy, Colorado Springs, Colorado, November 16, 1987. The papers address the modeling, systems identification, and control synthesis for the Spacecraft Control Laboratory Experiment (SCOLE) configuration.

N89-13463*# California Univ., Los Angeles. Dept. of Electrical Engineering.
SOME NONLINEAR DAMPING MODELS IN FLEXIBLE STRUCTURES
A. V. BALAKRISHNAN *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 54-66 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

A class of nonlinear damping models is introduced with application to flexible flight structures characterized by low damping. Approximate solutions of engineering interest are obtained for the model using the classical averaging technique of Krylov and Bogoliubov. The results should be considered preliminary pending further investigation. Author

N89-13470*# Purdue Univ., West Lafayette, IN.
PLACING DYNAMIC SENSORS AND ACTUATORS ON FLEXIBLE SPACE STRUCTURES
GREGORY A. NORRIS and ROBERT E. SKELTON *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 217-257 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

Input/Output Cost Analysis involves decompositions of the quadratic cost function into contributions from each stochastic input and each weighted output. In the past, these suboptimal cost decomposition methods of sensor and actuator selection (SAS) have been used to locate perfect (infinite bandwidth) sensor and actuators on large scale systems. This paper extends these ideas to the more practical case of imperfect actuators and sensors with dynamics of their own. NASA's SCOLE examples demonstrate that sensor and actuator dynamics affect the optimal selection and placement of sensors and actuators. Author

N89-13471*# California Univ., Berkeley. Dept. of Electrical Engineering and Computer Sciences.
OPTIMIZATION-BASED DESIGN OF CONTROL SYSTEMS FOR FLEXIBLE STRUCTURES
E. POLAK, T. E. BAKER, T-L. WUU, and Y-P. HARN *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 259-290 Oct. 1988
(Contract N00014-86-K-0295; AF-AFOSR-0116-86; NSF ECS-85-17362)
Avail: NTIS HC A17/MF A01 CSCL 22/2

The purpose of this presentation is to show that it is possible to use nonsmooth optimization algorithms to design both closed-loop finite dimensional compensators and open-loop optimal controls for flexible structures modeled by partial differential equations. An important feature of our approach is that it does not require modal decomposition and hence is immune to instabilities caused by spillover effects. Furthermore, it can be used to design control systems for structures that are modeled by mixed systems of coupled ordinary and partial differential equations. Author

N89-13472*# Naval Research Lab., Washington, DC.
EFFECT OF ACTUATOR DYNAMICS ON CONTROL OF BEAM FLEXURE DURING NONLINEAR SLEW OF SCOLE MODEL
SHALOM FISHER *In* NASA, Langley Research Center,

Proceedings of the 4th Annual SCOLE Workshop p 291-307 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

The effect of actuator dynamics on the control of beam flexure during nonlinear slewing of the SCOLE model is discussed. Two aspects of physical limitations on the regulation of beam flexure are similated, i.e., (1) a one foot travel limitation of displacement of proof-mass actuators; and (2) a time delay of 0.1 secs. in application of controls. The goal was to assess the magnitude of induced errors and, comparing the results to the ideal, and to determine how much flexure there is during slew and settling.
Author

N89-13486*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AN INTEGRATED IN-SPACE CONSTRUCTION FACILITY FOR THE 21ST CENTURY
MARTIN M. MIKULAS, JR. and JOHN T. DORSEY Nov. 1988 31 p
(NASA-TM-101515; NAS 1.15:101515) Avail: NTIS HC A03/MF A01 CSCL 22/2

Preliminary results are presented of studies being conducted by NASA on the construction of very large spacecraft. The various approaches are discussed for constructing spacecraft and their relative merits. It is observed that the Space Station Freedom has all of the basic design characteristics to permit its growth into an in-space construction facility for very large spacecraft. Also it is noted that if disturbances from construction operations are intolerable to other Space Station experiments, a co-orbiting construction facility could be built using previously developed Space Station truss hardware and systems. A discussion is also presented of a new PATHFINDER research initiative on on-orbit construction. This research effort is aimed at developing construction methods for very large spacecraft and includes the development of a 100 meter long space crane.
Author

N89-13815*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A SPACE CRANE CONCEPT: PRELIMINARY DESIGN AND STATIC ANALYSIS
MARTIN M. MIKULAS, JR., ROBERT C. DAVIS, and WILLIAM H. GREENE Nov. 1988 18 p
(NASA-TM-101498; NAS 1.15:101498) Avail: NTIS HC A03/MF A01 CSCL 20/11

Future in-space construction and assembly facilities will require the use of space cranes capable of supporting and manipulating large and massive loads. The large size of the space components being considered for construction will require that these cranes have a reach on the order of 100 meters. A space crane constructed from an erectable four-longeron truss beam with 19 5-sq-m truss bays is considered. This concept was selected to be compatible with the Space Station truss. This truss is hinged at three locations along its bottom edge and attached at one end to a rotary joint cantilevered to the assembly depot's main truss structure. The crane's boom sections are rotated by extensible longeron actuators located along the top edge of the beam. To achieve maximum position maneuvering capability for the crane requires that the individual sections be capable of rotating 180 degrees about the hinge point. This can only be accomplished by offsetting the hinges from the longeron axes. Since offset hinges introduce bending moments in the truss members, an analysis of the effect of hinge offsets on the load-carrying capacity of the structure is required. The objective of the static finite element analysis described is to determine the effect of various offset lengths on the overall bending stiffness of the crane and on the maximum stresses.
Author

N89-14901*# Lowell Univ., MA. Dept. of Mechanical and Energy Engineering.
SOME TEST/ANALYSIS ISSUES FOR THE SPACE STATION STRUCTURAL CHARACTERIZATION EXPERIMENT Abstract Only
CHAUR-MING CHOU *In* Hampton Inst., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988 p 48-49 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 22/2

The Space Station Structural Characterization Experiment (SSSCE) 1,2 is an early space flight experiment that uses the space station as a generic structure to study the dynamic characteristics of Large Space Structures (LSS). On-orbit modal testing will be conducted to determine natural frequencies, mode shapes and damping of dominant structural modes of the space structure assembly. This experiment will utimately support the development of system indentification and analytical modeling techniques for Large Space Structures. In order to ensure the success of SSSCE (in-space validation of modeling techniques for LSS), adequate measurement and instrumentation requirements have to be established during the experiment-definition study. Among the issues affecting these requirements, spatial and modal coverages of the modal test data are of particular interest. Topics such as total number of sensors, type of measurements (translation and rotation), optimal sensor locations (measurement degrees-of-freedom), selection of target modes, effects of modal superposition and truncation, separation of global and local modes, etc., are all a fundamental importance and must be investigated.
Author

N89-14925*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.
EXTENSION AND VALIDATION OF A METHOD FOR LOCATING DAMAGED MEMBERS IN LARGE SPACE TRUSSES Abstract Only
SUZANNE WEAVER SMITH *In* Hampton Inst., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988 p 97-98 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 22/2

The damage location approach employs the control system capabilities for the structure to test the structure and measure the dynamic response. The measurements are then used in a system identification algorithm to produce a model of the damaged structure. The model is compared to one for the undamaged structure to find regions of reduced stiffness which indicate the location of damage. Kabe's 3,4 stiffness matrix adjustment method was the central identification algorithm. The strength of his method is that, with minimal data, it preserves the representation of the physical connectivity of the structure in the resulting model of the damaged truss. However, extensive storage and computational effort were required as a result. Extension of the damage location method to overcome these problems is the first part of the current work. The central system identification algorithm is replaced with the MSMT method of stiffness matrix adjustment which was previously derived by generalizing an optimal-update secant method form quasi-Newton approaches for nonlinear optimization. Validation of the extended damage location method is the second goal.
Author

N89-14932*# Ohio State Univ., Columbus. Dept. of Engineering Mechanics.
THE INFLUENCE OF AND THE IDENTIFICATION OF NONLINEARITY IN FLEXIBLE STRUCTURES Abstract Only
LAWRENCE D. ZAVODNEY *In* Hampton Inst., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988 p 108-109 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 20/11

Several models were built at NASA Langley and used to demonstrate the following nonlinear behavior: internal resonance in a free response, principal parametric resonance and subcritical instability in a cantilever beam-lumped mass structure, combination resonance in a parametrically excited flexible beam, autoparametric interaction in a two-degree-of-freedom system, instability of the linear solution, saturation of the excited mode, subharmonic bifurcation, and chaotic responses. A video tape documenting these phenomena was made. An attempt to identify a simple structure consisting of two light-weight beams and two lumped masses using the Eigensystem Realization Algorithm showed the inherent difficulty of using a linear based theory to identify a particular

nonlinearity. Preliminary results show the technique requires novel interpretation, and hence may not be useful for structural modes that are coupled by a guadratic nonlinearity. A literature survey was also completed on recent work in parametrically excited nonlinear system. In summary, nonlinear systems may possess unique behaviors that require nonlinear identification techniques based on an understanding of how nonlinearity affects the dynamic response of structures. In this was, the unique behaviors of nonlinear systems may be properly identified. Moreover, more accutate quantifiable estimates can be made once the qualitative model has been determined. Author

N89-15155*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EXPERIENCES IN APPLYING OPTIMIZATION TECHNIQUES TO CONFIGURATIONS FOR THE CONTROL OF FLEXIBLE STRUCTURES (COFS) PROGRAM
JOANNE L. WALSH Oct. 1988 31 p Presented at the 2nd NASA/Air Force Symposium on Recent Advances in Multidisciplinary Analysis and Optimization, Hampton, VA, 28-30 Sep. 1988
(NASA-TM-101511; NAS 1.15:101511) Avail: NTIS HC A03/MF A01 CSCL 22/2

Optimization procedures are developed to systematically provide closely-spaced vibration frequencies. A general-purpose finite-element program for eigenvalue and sensitivity analyses is combined with formal mathematical programming techniques. Results are presented for three studies. The first study uses a simple model to obtain a design with two pairs of closely-spaced frequencies. Two formulations are developed: an objective function-based formulation and constraint-based formulation for the frequency spacing. It is found that conflicting goals are handled better by a constraint-based formulation. The second study uses a detailed model to obtain a design with one pair of closely-spaced frequencies while satisfying requirements on local member frequencies and manufacturing tolerances. Two formulations are developed. Both the constraint-based and the objective function-based formulations perform reasonably well and converge to the same results. However, no feasible design solution exists which satisfies all design requirements for the choices of design variables and the upper and lower design variable values used. More design freedom is needed to achieve a fully satisfactory design. The third study is part of a redesign activity in which a detailed model is used. The use of optimization in this activity allows investigation of numerous options (such as number of bays, material, minimum diagonal wall thicknesses) in a relatively short time. The procedure provides data for judgments on the effects of different options on the design. Author

N89-15161 Missouri Univ., Rolla.
MODELING AND CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES Ph.D. Thesis
JAYANT V. RAMAKRISHNAN 1988 230 p
Avail: Univ. Microfilms Order No. DA8816024

Simulation of space structures forms a critical part of the space station design process. The distributed parameter system is discretized by the finite element technique and represented by a finite set of ordinary differential equations. However, from the viewpoint of control computations, the dimensions of the finite element matrices are too large. A lower order model based on some criteria is derived via the process of aggregation and is used for simulation purposes. The thesis investigates the merits and demerits of some model reduction techniques as addressed to this specific problem. A simple and intuitively appealing degree-of-controllability definition is derived that enhances the approach to the actuator/sensor placement problem. Controller synthesis for a realistic space station, the associated spillover, bounds of suboptimality and the performance degradation are investigated. The balanced realization technique and the Routh approximation method are used in the synthesis of lower order models. The simulations include vibration suppression and minimization of line-of-sight errors. Results indicate that controllers derived using reduced order models perform very well.
Dissert. Abstr.

N89-15431# National Aerospace Lab., Amsterdam (Netherlands). Space Div.
ACCURACY OF MODAL FREQUENCY SET WITH FICTITIOUS JOINTS MODELING
P. TH. L. M. VANWOERKOM 26 May 1987 32 p Sponsored by the Netherlands Agency for Aerospace Programs, Delft
(NLR-TR-87126-U; ETN-89-93887) Avail: NTIS HC A03/MF A01

The accuracy of the fictitious joints modeling technique is assessed relative to the standard distributed parameter modeling technique. The system is a pinned-pinned Euler-Bernouilli beam. The accuracy criterion is the error in the modal frequencies for the two modeling techniques. The accuracy of the fictitious joints model is very good, although it degrades with increasing mode number. Inaccuracies in the modal frequencies may (after system assembly) lead to errors in those modal frequencies that are located within the bandwith of interest of the assembled system. The modal frequencies for the fictitious joints model are always lower than those for the truth model. This is a convenient property when choosing integration step sizes for numerical simulations. ESA

N89-15433*# Catholic Univ. of America, Washington, DC. Dept. of Mechanical Engineering.
ACTIVE CONTROL OF BUCKLING OF FLEXIBLE BEAMS Final Report
A. BAZ and L. TAMPE 19 Jan. 1989 35 p
(Contract NAG5-520)
(NASA-CR-183333; NAS 1.26:183333) Avail: NTIS HC A03/MF A01 CSCL 20/11

The feasibility of using the rapidly growing technology of the shape memory alloys actuators in actively controlling the buckling of large flexible structures is investigated. The need for such buckling control systems is becoming inevitable as the design trends of large space structures have resulted in the use of structural members that are long, slender, and very flexible. In addition, as these truss members are subjected mainly to longitudinal loading they become susceptible to structural instabilities due to buckling. Proper control of such instabilities is essential to the effective performance of the structures as stable platforms for communication and observation. Mathematical models are presented that simulate the dynamic characteristics of the shape memory actuator, the compressive structural members, and the associated active control system. A closed-loop computer-controlled system is designed, based on the developed mathematical models, and implemented to control the buckling of simple beams. The performance of the computer-controlled system is evaluated experimentally and compared with the theoretical predictions to validate the developed models. The obtained results emphasize the importance of buckling control and suggest the potential of the shape memory actuators as attractive means for controlling structural deformation in a simple and reliable way.
Author

N89-15438*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FREE-VIBRATION CHARACTERISTICS AND CORRELATION OF A SPACE STATION SPLIT-BLANKET SOLAR ARRAY
KELLY S. CARNEY and FRANCIS J. SHAKER 1989 15 p Prepared for presentation at the 30th Structures, Structural Dynamics and Materials Conference, Mobile, AL, 3-5 Apr. 1989; sponsored in part by AIAA, ASME, ASCE, AHS and ACS
(NASA-TM-101452; E-4563; NAS 1.15:101452) Avail: NTIS HC A03/MF A01 CSCL 20/11

Two methods for studying the free-vibration characteristics of a large split-blanket solar array in a zero-g cantilevered configuration are presented. The zero-g configuration corrresponds to an on-orbit configuration of the Space Station solar array. The first method applies the equations of continuum mechanics to determine the natural frequencies of the array; the second uses the finite element method program, MSC/NASTRAN. The stiffness matrix from the NASTRAN solution was found to be erroneously

grounded. The results from the two methods are compared. It is concluded that the grounding does not seriously compromise the solution to the elastic modes of the solar array. However, the correct rigid body modes need to be included to obtain the correct dynamic model. Author

N89-15970*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A COMPARISON OF TWO TRUSSES FOR THE SPACE STATION STRUCTURE
THOMAS R. SUTTER and HAROLD G. BUSH Washington, DC Mar. 1989 23 p
(NASA-TM-4093; L-16540; NAS 1.15:4093) Avail: NTIS HC A03/MF A01 CSCL 22/2

The structural performance of two truss configurations, the orthogonal tetrahedral and a Warren-type, are compared using finite element models representing the November Reference Phase 1 Space Station. The truss torsional stiffness properties and fundamental torsion frequency are determined using cantilever truss-beam models. Frequencies, mode shapes, transient response, and truss strut compressive loads are compared for the two space station models. The performance benefit resulting from using a high modulus truss strut is also presented. Finally, assembly and logistics characteristics of the two truss configurations are evaluated. Author

N89-15971# Business and Technological Systems, Inc., Laurel, MD.
ALGORITHMS FOR ROBUST IDENTIFICATION AND CONTROL OF LARGE SPACE STRUCTURES, PHASE 1 Final Report, Aug. 1987 - Mar. 1988
JAMES V. CARROLL 14 May 1988 85 p Sponsored in part by SDIO/Innovative Science and Technology Office, Washington, DC
(Contract F49620-87-C-0099)
(AD-A198130; BTS63-88-34/AB; J1131; AFOSR-88-0755TR)
Avail: NTIS HC A05/MF A01 CSCL 22/1

A new method of providing robust attitude control for tracking and slewing maneuvers for large flexible space structures in orbit is developed, and preliminary analyses and performance studies are conducted. The key elements of the method are system identification in real time, based on canonical variate analysis, and adaptive robust control using Model Predictive Control. The Canonical Variate Analysis method also possesses the built-in capability for performing statistically optimal model order reduction. Computational algorithms are developed using several low order flexible models. The results of this feasibility effort demonstrate that the new method is subject to careful design to reduce computer core size problems, but that its overall performance offers encouraging potential for more complete development. GRA

N89-15973# SatCon Technology Corp., Cambridge, MA.
DISTRIBUTED MAGNETIC ACTUATORS FOR FINE SHAPE CONTROL Final Report, Jul. 1987 - Jan. 1988
GEORGE ANASTAS, DAVID EISENHAURE, RICHARD HOCKNEY, BRUCE JOHNSON, and KATHLEEN MISOVEC Jun. 1988 91 p
(Contract F04611-87-C-0047)
(AD-A199287; R01-88; AFAL-TR-88-026) Avail: NTIS HC A05/MF A01 CSCL 22/2

New spacecraft designs feature large structures characterized by low natural frequencies and stringent pointing and vibration requirements. These large space structures pose unique and difficult control problems. These problems include system bandwidths greater than structural natural frequencies; lack of accurate information about the dynamic characteristic of the structure being controlled; complicated high-order dynamics, including non-linear behavior; and stringent requirements for distributed shape control. An important part of the solution to these control problems is the development of actuators capable of applying force or torque to the structures. Conventionally these actuators have been reaction mass actuators or distributed piezoelectric materials. The objective of this research program was to investigate other innovative actuator designs for use in flexible spacecraft structure control. In particular, actuators based on the direct use of electromagnetic forces were developed. GRA

N89-16193*# Ohio State Univ., Columbus. Dept. of Aeronautical and Astronautical Engineering.
A NOVEL APPROACH IN FORMULATION OF SPECIAL TRANSITION ELEMENTS: MESH INTERFACE ELEMENTS Status Report
NESRIN SARIGUL Jan. 1989 67 p
(Contract NAG3-790; RF PROJ. 765939/719301)
(NASA-CR-184768; NAS 1.26:184768) Avail: NTIS HC A04/MF A01 CSCL 20/11

The objective of this research is to develop more accurate and efficient advanced methods for solution of singular problems encountered in various branches of mechanics. The research program includes the formulation of new class elements called Mesh Interface Elements (MIE) to connect meshes of traditional elements either in three dimensions or in three and two dimensions. The finite element formulations are based on the boolean sum and blending operators. In today's advanced aircraft and space structure applications, steep temperature and/or stress gradients are commonly encountered. The analysis methods need to incorporate these steep gradients into the solution efficiently and accurately. Mesh Interface Elements are formulated and tested to account for the steep gradient effects. At present, the heat transfer and structural analysis problems are formulated from uncoupled theory point of view. The status report, first, summarizes the general formulation for heat transfer and structural analysis by including the newly introduced varying material properties at material nodal points of the elements concept. The the formulation of mesh interface elements is detailed. On the computational efficiency side, a hidden-symbolic computation concept developed by the author is given. Verfication examples are included from the heat transfer and structural analysis problems. The appendix includes listings of the computer modules developed for this purpose. Author

N89-16194*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
REDUCING DISTORTION AND INTERNAL FORCES IN TRUSS STRUCTURES BY MEMBER EXCHANGES
WILLIAM H. GREENE and RAPHAEL T. HAFTKA (Virginia Polytechnic Inst. and State Univ., Blacksburg.) Jan. 1989 26 p
(NASA-TM-101535; NAS 1.15:101535) Avail: NTIS HC A03/MF A01 CSCL 20/11

Manufacturing errors in the length of members or joint diameters of large truss reflector backup structures may result in unacceptable large distortion errors or member forces. However, it may be possible to accurately measure these length or diameter errors. The present work suggests that a member and joint placement strategy may be used to reduce distortion errors and internal member forces. A member and joint exchange algorithm is used to demonstrate the potential of this approach on several 102-member and 660-member truss reflector structures. It is shown that it is possible to simultaneously reduce the rms of the surface error and the rms of member forces by two orders of magnitude by member and joint exchanges. Author

N89-19333# Virginia Univ., Charlottesville. Dept. of Mechanical and Aerospace Engineering.
PROCEEDINGS OF THE FIFTH AFOSR FORUM ON SPACE STRUCTURES
WALTER D. PILKEY, ed. and ROBERT L. KOSUT, ed. (Integrated Systems, Inc., Palo Alto, CA.) 11 Dec. 1987 92 p Forum held at Monterey, Calif., 20-21 Aug. 1987
(Contract F49620-86-K-0009; AF PROJ. 2302)
(AD-A194761; AFOSR-88-0477TR; UVA/525673/MAE88/102)
Avail: NTIS HC A05/MF A01 CSCL 22/5

This is the Proceedings of the Fifth AFOSR Forum on Space Structures. The topics covered include modeling of spacecraft, wave propagation in large space structures, multiflexible body

dynamic simulation, adaptive structures, electromechanical actuators for controlling flexible structures, system identification of suboptimal control parameters, integrated structural analysis and control, active control of elastic wave motion in structural networks, adaptive control of large space structures; analysis of performance degradation, optimal projection equations for fixed-order dynamic compensation, decentralized/relegated control for large space structures, Frobenius-Hankel norm framework for disturbance rejection and low order decentralized controller design, a method for truss structure vibration control, and robust eigenstructure assignment by a projection method.

N89-19334# Howard Univ., Washington, DC. Dept. of Mechanical Engineering.
MODELING OF FLEXIBLE SPACECRAFT ACCOUNTING FOR ORBITAL EFFECTS
PETER M. BAINUM *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 3-8 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

Many current investigations of the shape and orientation control of proposed flexible orbiting large space structures (LSS) do not incorporate the effects of the gravity-gradient and orbital dynamic coupling into the plant models. This means that for the corresponding linearized unforced, open-loop systems, the poles of the rigid rotational modes are at the origin. The manner in which the orbitally induced coupling effects, due to gravity-gradient and gyroscopic effects, are introduced is clearly indicated in the continuum formulation of Santini for predicting the motion of a general orbiting flexible body in orbit. These coupling terms reflect both coupling between the rigid and flexible motions and also intra-modal coupling effects. Elastic deformations are considered small as compared with characteristic body dimensions. Equations are developed for both the rigid and elastic (generic) motions, based on an a prior knowledge of the frequencies and shape functions of all modes included within the truncated system model. The orbitally induced coupling terms are seen to depend on volume integrals whose integrands are functions of the various components of the different modal shape functions together with the coordinates of the differential mass elements. Author

N89-19335# Massachusetts Inst. of Tech., Cambridge. Dept. of Mechanical Engineering.
WAVE PROPAGATION IN LARGE SPACE STRUCTURES
JAMES H. WILLIAMS, JR. and RAYMOND J. NAGEM *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 9-11 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

The first step in the mathematical analysis of any physical system is the selection of a mathematical model to represent the system. This selection is extremely important, since it not only determines in advance the scope of possible results of the analysis, but also heavily influences the design of auxiliary devices and systems, such as control systems. In the dynamic analysis of large space structures, mathematical models have consisted primarily of a set of vibration modes. The popularity of the modal vibration model of large space structures is due partly to the well-developed analytical techniques which can be applied to such a model, and partly to the success with which modal vibration models have been used to describe structures on earth. However, in view of the unprecedented size of large space structures and their potential technological importance, it is worthwhile to examine the limitations of modal vibration models and to consider the usefulness of other models. A particular concern here is with models which view large space structures as media in which wave propagation provides an accurate dynamic description. Author

N89-19338# Jet Propulsion Lab., California Inst. of Tech., Pasadena. Applied Technologies Section.
CONCEPT OF ADAPTIVE STRUCTURES
MICHAIL ZAK *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 23-24 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

The concept of adaptive structures is brought up in connection with the need in ultra lightweight structural systems to maintain desired properties and configurations without human intervention when subjected to dynamic, thermal, and other environmental forces. Examples are large antenna structures and flexible robotic structures. In the both cases such adaptivity would allow less massive structural members to be employed under normal loading conditions. During special circumstances when unusually large loads are encountered, temporary stiffening would allow the use of less sturdy structures, resulting in large savings in their cost, and in increasing their mobility and efficiency. Within the framework of a finite-dimensional representation of structural dynamics, the adaptivity can be implemented by the dependence of the stiffness matrix (k) upon the expected load (Q), or expected (programmed) changes in configurations, i.e., (k) = (k(t)) where the dependence upon time is programmed in advance. In order to sustain unexpected loads the adaptive structure can be provided by feedback force control, or by a parametrical stiffness control. Author

N89-19339# State Univ. of New York, Buffalo. Dept. of Mechanical and Aerospace Engineering.
COMMENTS ON ELECTROMECHANICAL ACTUATORS FOR CONTROLLING FLEXIBLE STRUCTURES
D. J. INMAN, R. W. MAYNE, and D. C. ZIMMERMAN (Florida Univ., Gainesville.) *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 25-27 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

Two types of specific electromechanical actuators are described and discussed. A proof mass actuator and an electric motor are examined in terms of the amount of damping each produces in a specific structural control experiment. Theoretical and experimental values of actuator produced damping are examined. The effects of actuator dynamics on control law implementation are noted. In addition, a theoretical parameter study of the dynamic response of a dc motor controlling a flexible model of a beam are summarized. Author

N89-19341# Aerospace Corp., Los Angeles, CA.
INTEGRATED STRUCTURAL ANALYSIS AND CONTROL (ISAAC): ISSUES AND PROGRESS
M. ASWANI, D. S. FLAMM, C. L. GUSTAFSON, A. B. JENKIN, J. D. KAWAMOTO, and G. T. TSENG *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 43-47 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

The ISAAC program at the Aerospace Corporation has been pursuing issues which arise in the simultaneous design of structures and control systems for large space structures using a mathematical programming code. There are many practical advantages to such integrated design, such as tuning the structure to directly improve the closed loop performance measure. Here, the focus is on key elements in the work, and in particular those elements which distinguish our emphasis from that of other workers in the field. There is obviously more to gain by simultaneously tuning structural and controller designs. Closed loop performance criteria which directly measure desired characteristics are available. The big issues are parametrization of controller and structure, and computational techniques for evaluation of criteria, constraints, and their derivatives. Author

N89-19349*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ROBUST EIGENSTRUCTURE ASSIGNMENT BY A PROJECTION METHOD: APPLICATION USING MULTIPLE OPTIMIZATION CRITERIA
J. L. JUNKINS, D. W. REW, and J. N. JUANG *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 85-88 11 Dec. 1987 Sponsored by NASA
Avail: NTIS HC A05/MF A01 CSCL 22/5

New ideas which lead to feedback control laws for large flexible structures which are insensitive to model uncertainty are presented. A pole placement method is presented which leads to near-unitary closed loop eigenvectors, and a new method is introduced to

design the control while simultaneously considering three competing measures of optimality. Robustness versus Integral algorithms are applicable to at least moderately high-dimensioned systems. In the present discussion, controls for two coupled flexible bodies are considered. A 6x24 gain matrix is designed to control a 12 modes system using 6 actuators. Researchers also developed control laws for the R2P2 simulator at Martin Marietta; in this case 3 actuators are used to control a 12th order system. Simulation studies indicate that researchers indeed achieved robust designs without significant difficulties associated with spillover into the uncontrolled modes. Here, several key ideas and numerical results are given. In the references, details of the formulation, discussions of salient features, and connection to the availiable literature are given. Author

N89-19350 Virginia Polytechnic Inst. and State Univ., Blacksburg.
DAMAGE DETECTION AND LOCATION IN LARGE SPACE TRUSSES Ph.D. Thesis
SUZANNE WEAVER SMITH 1988 139 p
Avail: Univ. Microfilm Order No. DA8817424

Researchers pursuing the goal to design and construct a large orbiting space structure are directing considerable effort toward many issues, including the ability to maneuver a flexible structure. In particular, basic research is underway into the technologies of control system design and structural modeling to support this effort. The thesis of this research is that structural damage can be detected and located with the control system of a large space structure. A concept for damage location was developed and demonstrated in simulated tests. The control system tests the structure and measures the response. The measurement are then used in a system identification algorithm to produce a model of the damaged structure. The model is compared to one for the undamaged structure to find regions of reduced stiffness which indicate the location of damage. Simulation studies were performed on two truss models. The members of both and the design of the second were borrowed form the concept design for the Space Station. Exact and inexact data simulated tests with the two structures indicated that damage can be located with this approach. Dissert. Abstr.

N89-19357# Harris Corp., Melbourne, FL. Government Aerospace Systems Div.
EXPERIMENTAL VERIFICATION OF AN INNOVATIVE PERFORMANCE-VALIDATION METHODOLOGY FOR LARGE SPACE SYSTEMS Annual Report, Aug. 1987 - Aug. 1988
DAVID C. HYLAND Sep. 1988 53 p
(Contract F49620-87-C-0108)
(AD-A202243; AFOSR-88-1192TR) Avail: NTIS HC A04/MF A01 CSCL 22/2

A technology gap exists in verifying performance of large space systems. To fill that gap the proposed program seeks to develop and validate an efficient pre-flight performance verification methodology. The approach involves selective component testing along with analysis of subsystem interactions. The method exploits MEOP (Maximum Entropy/Optimal Projection) Control-System Design and Majorant Robustness Analysis. The approach will be formulated for several representative large space systems and experimentally verified on a 3-meter diameter multi-hex panel ground-based active controls testbed. GRA

N89-19358# Harris Corp., Melbourne, FL. Government Aerospace Systems Div.
MAXIMUM ENTROPY/OPTIMAL PROJECTION DESIGN SYNTHESIS FOR DECENTRALIZED CONTROL OF LARGE SPACE STRUCTURES Final Report, Oct. 1986 - May 1988
DAVID C. HYLAND, DENNIS S. BERNSTEIN, and EMMANUEL G. COLLINS, JR. May 1988 281 p
(Contract F49620-86-C-0038)
(AD-A202375; AFOSR-88-1203TR) Avail: NTIS HC A13/MF A01 CSCL 22/2

The Maximum Entropy/Optimal Projection (MEOP) Methodology is a novel approach to designing implementable vibration-suppression controllers for large space systems. Two issues, in particular, have been addressed, namely, controller order (i.e., complexity) and system robustness (i.e., sensitivity to plant variations). Extensions developed herein include generalizations to decentralized controller architectures and a new robustness analysis technique known as Majorant Robustness Analysis. This final report also encompasses extensions to hierarchical control as well as the development of numerical algorithms for solving the control design equations. GRA

N89-19362# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (West Germany). Space Flight Dynamics Section.
INVESTIGATION OF FLIGHT SENSORS AND ACTUATORS FOR THE VIBRATION DAMPING AUGMENTATION OF LARGE FLEXIBLE SPACE STRUCTURES Final Report
TH. LANGE, comp. Paris, France ESA May 1988 237 p
(Contract ESTEC-6902/86-NL-MAC(SC))
(ESA-CR(P)-2670; ETN-89-93926) Avail: NTIS HC A11/MF A01

Sensor and actuator hardware was analyzed with respect to a two-dimensional generic structural model representing a material processing platform on a large space structure. Two devices based on inertial control for vibration damping are presented. The Rotating Resonance InTegrating Accelerometer (RITA) is based upon a rotating pendulum to be applied for inertial acceleration measurement without any bias or stiction effect associated with ordinary servoed proof-mass accelerometers. The RITA features the suspension of the rotating proof-mass by a spring assembly tuned in resonance with the rotor spin frequency. Thus high measurement sensitivity and a high axial stiffness can be realized. The LInear Stepper Motor Actuator (LISA) is proposed as an alternative with respect to the pivoted proof-mass actuators. In LISA the proof-mass incorporates the motor coils, which are attached to a lightweight carriage by a spring/damper assembly. Thus high stepping rates with low switching times can be realized with relatively low motor power. This kind of proof-mass suspension damps out the high frequency noise level to a large extent. Semiactive hydraulic control methods utilizing the energy dissipation property of viscous fluids flowing through special surface treated pipes to increase the frictional effect are also presented. Due to the high weight penalty they are not suitable for structures represented by the box truss model but could be applied for structures extending over several hundred meters. This is due to the expected high damping forces requiring a smaller number of actuators and reducing the relative weight penalty. ESA

04

THERMAL CONTROL

Includes descriptions of analytical techniques, passive and active thermal control techniques, external and internal thermal experiments and analyses and trade studies of thermal requirements.

A89-11418
IMPORTANCE OF HEAT TRANSFER IN LI/MOS2 BATTERIES FOR AEROSPACE APPLICATIONS
C. J. JOHNSON (Boeing Aerospace Co., Seattle, WA) IN: Symposium on Primary and Secondary Ambient Temperature Lithium Batteries, Honolulu, HI, Oct. 18-23, 1987, Proceedings. Pennington, NJ, Electrochemical Society, Inc., 1988, p. 458-463.

Heat transfer measurements of Li/MoS2 batteries revealed that heat was absorbed when charging between 25-75 percent state of charge. This range of charge correlates with test data for charge/discharge cycling found to optimize cycle life. For space applications, the beneficial aspect of cooling on charging would allow a lighter weight total power subsystem. Heat generation during discharge was found to be comparable to that of other space batteries. Author

A89-15190* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE DESIGN AND FABRICATION OF A STIRLING ENGINE HEAT EXCHANGER MODULE WITH AN INTEGRAL HEAT PIPE
JEFFREY G. SCHREIBER (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 1. New York, American Society of Mechanical Engineers, 1988, p. 133-140. Previously announced in STAR as N88-26732. refs

The conceptual design of a free-piston Stirling Space Engine (SSE) intended for space power applications has been generated. The engine was designed to produce 25 kW of electric power with heat supplied by a nuclear reactor. A novel heat exchanger module was designed to reduce the number of critical joints in the heat exchanger assembly while also incorporating a heat pipe as the link between the engine and the heat source. Two inexpensive verification tests are proposed. The SSE heat exchanger module is described and the operating conditions for the module are outlined. The design process of the heat exchanger modules, including the sodium heat pipe, is briefly described. Similarities between the proposed SSE heat exchanger modules and the LeRC test modules for two test engines are presented. The benefits and weaknesses of using a sodium heat pipe to transport heat to a Stirling engine are discussed. Similarly, the problems encountered when using a true heat pipe, as opposed to a more simple reflux boiler, are described. The instruments incorporated into the modules and the test program are also outlined. Author

A89-15207
HIGH POWER INFLATABLE RADIATOR FOR THERMAL REJECTION FROM SPACE POWER SYSTEMS
D. CHITTENDEN, G. GROSSMAN, E. ROSSEL, P. VAN ETTEN, and G. WILLIAMS (L'Garde, Inc., Tustin, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 1. New York, American Society of Mechanical Engineers, 1988, p. 353-358. refs
(Contract F33615-87-C-2752)

The present study has investigated a novel concept of an inflatable radiator which captures burst heat from space-based defense systems during its short generation period and radiates it to space later over a longer period. During the operation phase, the radiator is extended out of the spacecraft and filled with steam generated by the waste heat. As the spacecraft continues orbiting the earth, the steam is condensed gradually. The radiator is retracted during condensation so as to maintain a constant saturation pressure, and is folded neatly into the spacecraft, ready for the next mission. A preliminary design of the inflatable radiator has been performed during which various aspects of its operation were studied. The paper discusses the results of these studies including the choice and evaluation of candidate materials, design of the bag with the retraction, folding and drive mechanisms, the thermal, dynamic stability and survivability analyses. Author

A89-15208* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
MOVING BELT RADIATOR TECHNOLOGY ISSUES
K. ALAN WHITE, III (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 1. New York, American Society of Mechanical Engineers, 1988, p. 365-371. Previously announced in STAR as N88-25477. refs

Development of the Moving Belt Radiator (MBR) as an advanced space radiator concept is discussed. The relative merits of Solid Belt (SBR) Liquid Belt (LBR), and Hybrid Belt (HBR) Radiators are described. Analytical and experimental efforts related to the dynamics of a rotating belt in microgravity are reviewed. The development of methods for transferring heat to the moving belt is discussed, and the results from several experimental investigations are summarized. Limited efforts related to the belt deployment and stowage, and to fabrication of a hybrid belt, are also discussed. Life limiting factors such as seal wear and micrometeroid resistance are identified. The results from various MBR point design studies for several power levels are compared with advanced Heat Pipe Radiator technology. MBR designs are shown to compare favorable at both 300 and 1000 K temperature levels. However, additional effort will be required to resolve critical technology issues and to demonstrate the advantage of MBR systems. Author

A89-15209* Los Alamos National Lab., NM.
TRANSIENT PERFORMANCE EVALUATION OF AN INTEGRATED HEAT PIPE-THERMAL STORAGE SYSTEM
E. KEDDY, J. T. SENA, M. MERRIGAN (Los Alamos National Laboratory, NM), GARY HEIDENREICH (Sundstrand Corp., Rockford, IL), and STEVE JOHNSON (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 1. New York, American Society of Mechanical Engineers, 1988, p. 373-378.

Transient performance tests of an integrated heat pipe-thermal storage system have been conducted. This system was developed as a part of an Organic Rankine Cycle-Solar Dynamic Power System receiver for future power systems. The integrated system consists of potassium heat pipe elements that incorporate thermal energy storage canisters within the vapor space and an organic fluid (toluene) heater tube used as the condenser region of the heat pipe. The transient performance tests determined the operating characteristics and power input limits of the integrated heat pipe-thermal storage unit under conditions corresponding to re-acquisition of the sun during emergence from eclipse conditions and to the initial start-up of the solar dynamic power system. The tests demonstrated that the heat pipe-thermal storage element is not limited under conditions corresponding to emergence from eclipse during normal orbital operations and the heat pipe will successfully start-up from the frozen condition with full input power at the onset. Details of the test procedures and results of the tests are presented in this paper. Author

A89-15210
HEAT PUMP AUGMENTED RADIATOR FOR LOW-TEMPERATURE SPACE APPLICATIONS
M. OLSZEWSKI (Oak Ridge National Laboratory, TN) and U. ROCKENFELLER (Rocky Research Corp., Boulder City, NV) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 1. New York, American Society of Mechanical Engineers, 1988, p. 379-383. USAF-supported research. refs
(Contract DE-AC05-84OR-21400)

Closed-cycle, space-based heat rejection systems depend solely on radiation to achieve their heat dissipation function. Since the payload heat rejection temperature is typically 50 K above that of the radiation sink in near earth orbit, the size and mass of these systems can be appreciable. Size (and potentially mass) reductions are achievable by increasing the rejection temperature via a heat pump. Two heat pump concepts were examined to determine if radiator area reductions could be realized without increasing the mass of the heat rejection system. The first was a conventional, electrically-driven vapor compression system. The second is an innovative concept using a solid-vapor adsorption system driven by reject heat from the prime power system. The mass and radiator area of the heat pump radiator systems were compared to that of a radiator only system to determine the merit of the heat pump concepts. Results for the compressor system indicated that the mass minimum occurred at a temperature lift of about 50 K and radiator area reductions of 35 percent were realized. With a radiator specific mass of 10 kgm, the heat pump system is 15 percent higher than the radiator only baseline system. Author

A89-25064*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
THE SPACE STATION ACTIVE THERMAL CONTROL TECHNICAL CHALLENGE
W. E. ELLIS (NASA, Johnson Space Center, Houston, TX) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs
(AIAA PAPER 89-0073)

The overall conceptual design premise of the two major subsystems that make up the Space Station active thermal control system is discussed. Specifically, the thermal loop required to gather and collect the waste heat from the various systems, modules, and payloads of the Space Station and the large radiators necessary to dissipate the waste heat to space are described. The basic design concepts to be incorporated in the Space Station are described, and the ground and flight tests conducted to date to prove the feasibility of the design approaches are summarized. Future Space Shuttle flight tests planned to further verify the designs are outlined. Author

A89-25068#
HEAT-PUMP-AUGMENTED RADIATOR FOR HIGH POWER SPACECRAFT THERMAL CONTROL
B. L. DROLEN (Hughes Aircraft Co., Los Angeles, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(Contract F33615-85-C-2557)
(AIAA PAPER 89-0077)

A simple model of a heat-pump-augmented spacecraft is used to study the effect of the heat pump on the overall mass and total radiator area of spacecraft employing one of four different power sources capable of generating 10-100 kW of electrical power. It is demonstrated that significant radiator area and system mass saving can be achieved with heat pumps having a specific mass of about 10 kg/kW(cooled) or lower. Heat pumps using waste heat generated by the power source provide greater mass savings than those that use the generated electrical energy. R.R.

A89-25271*# NASA Space Station Program Office, Reston, VA.
AN INTEGRATED MODEL OF THE SPACE STATION FREEDOM ACTIVE THERMAL CONTROL SYSTEM
JOHN J. TANDLER (Grumman Corp., Grumman Space Station Freedom Program Support Div., Reston, VA) and VINCENT J. BILARDO, JR. (NASA, Space Station Freedom Program Office, Reston, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0319)

A flexible, generic model of the Space Station Freedom active thermal control system has been developed which is designed to analyze dynamic interactions of the major subsystems of the ATCS. Models are described for the components of the central thermal bus, the radiator external thermal environment, and the internal thermal control system. Two programs are described which facilitate the development of the integrated ATCS model. The first, SIMRAD, simplifies an external thermal environment model given a desired level of accuracy in integrated model performance. The model reduction technique is shown to reduce model execution time significantly while maintaining the desired accuracy. The second, GENFLU, generates SINDA/FLUINT input code for the evaporator and load interface models and automates the integration of load submodels. The component submodels and integration techniques were used to create an integrated model of the thermal control system for an early assembly flight configuration. The results demonstrate the utility of the integrated model in studying dynamic interactions of the ATCS subsystems. Author

A89-27824
IMPROVEMENTS IN PASSIVE THERMAL CONTROL FOR SPACECRAFT
A. M. WHALLEY (Pilkington PE, Ltd., Space Technology, Bodelwyddan, Wales) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 7 p.
(SAE PAPER 881022)

This paper presents test results and suggestions for improvement as part of an overall optimization program for passive thermal control Optical Solar Reflectors (OSRs). The OSR acts as a thermal control device for satellites by reflecting incident solar radiation while simultaneously radiating internally generated heat harmlessly into the surrounding environment. Options for the enhancement of OSR thermal properties, through the use of thermal control coatings, by either a reduction in the overall solar absorptance or an increase in the IR emittance are discussed. A process of strength enhancement of the OSRs by immersion in an acid solution is also examined. The author concludes by suggesting a reexamination of protective coatings already used on the existing product. S.A.V.

A89-27863* Grumman Aerospace Corp., Bethpage, NY.
PROTOTYPE SPACE ERECTABLE RADIATOR SYSTEM GROUND TEST ARTICLE DEVELOPMENT
JOSEPH P. ALARIO (Grumman Corp., Space Systems Div., Bethpage, NY) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 12 p. refs
(Contract NAS9-17498)
(SAE PAPER 881066)

A prototype heat rejecting system is being developed by NASA-JSC for possible space station applications. This modular system, the Space-Erectable Radiator System Ground Test Article (SERS-GTA) with high-capacity radiator panels, can be installed and replaced on-orbit. The design, fabrication and testing of a representative ground test article are discussed. Acceptance test data for the heat pipe radiator panel and the whiffletree clamping mechanism have been presented. A.A.F.

A89-27864* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
LONG-LIFE/DURABLE RADIATOR COATINGS FOR SPACE STATION
STEVE JACOBS (NASA, Johnson Space Center, Houston, TX) and DONALD R. DUFFY (Acurex Corp., Mountain View, CA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p.
(SAE PAPER 881067)

The anodic coatings developed by anodizing specific aluminum alloys show considerable promise as long-life/durable radiator coatings. These coatings, formed by the sulfuric acid anodizing process, were the best performers of a variety of candidate coatings subjected to ultraviolet radiation and temperature-cycling tests. Author

A89-27865* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SPACE STATION THERMAL TEST BED STATUS AND PLANS
TIMOTHY K. BRADY (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 16 p. refs
(SAE PAPER 881068)

The accomplishments, current status, and future plans of the thermal test bed program for Space Station thermal management are discussed. This program is intended to support the design and development of the thermal control systems for the Space Station. The topics discussed include heat pipe radiator evaluation, modular panel tests, two-phase heat transport, and testing of thermal buses using ammonia as the working fluid. A.A.F.

A89-27866* NASA Space Station Program Office, Reston, VA.
SPACE STATION THERMAL CONTROL DURING ON-ORBIT ASSEMBLY
VINCENT J. BILARDO, JR. (NASA, Space Station Freedom Program Office, Reston, VA) and ALBERT W. CARLSON (Grumman Corp., Space Station Program Support Div., Reston, VA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 17 p. refs
(SAE PAPER 881070)

This paper summarizes the Space Station program requirements for the Thermal Control System (TCS), and outlines the capabilities of the TCS for each assembly configuration. The TCS architecture for the completed assembly configuration is described, consisting of an active TCS (ATCS) and a passive TCS (PTCS). The four ATCS subsystems are described, including the two-phase ammonia central ATCS, photovoltaic power module, attached payload accommodation equipment and the single-phase water internal ATCS. Author

A89-27880* Sundstrand Corp., Rockford, IL.
REDUCED GRAVITY AND GROUND TESTING OF A TWO-PHASE THERMAL MANAGEMENT SYSTEM FOR LARGE SPACECRAFT
D. G. HILL, K. HSU (Sundstrand Corp., Rockford, IL), R. PARISH, and J. DOMINICK (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 14 p. refs
(Contract NAS9-17195)
(SAE PAPER 881084)

Experiments were performed aboard the NASA-JSC KC-135 aircraft to study the effect of reduced gravity on two-phase (liquid/vapor) flow and condensation. A prototype two-phase thermal management system for a large spacecraft was tested. Both visual observation and photography of the flow regimes were made. Ground test simulations of the KC-135 flight tests were conducted for comparison purposes. Two-phase pressure drops were predictable by the Heat Transfer Research Institute (HTRI) method, or the Friedel correlation. A.A.F.

A89-27881
FLOSIN - A FLUID LOOP ANALYZER FOR SINDA
STEVEN M. LUNDE (Boeing Aerospace, Seattle, WA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 13 p.
(SAE PAPER 881085)

By interfacing the computer code FLOSIN (a stand-alone program for adiabatic fluid loop analysis) with SINDA (Systems Improved Numerical Differencing Analyzer), a combined thermal/fluid analysis of fluid loops can be performed. FLOSIN is essentially a library of subroutines accessed by the user. System temperatures and pressures on existing thermal bus can be predicted. A prototype two-phase thermal bus using ammonia as the working fluid has been developed for potential Space Station applications. A.A.F.

A89-27882
DESIGN OF A TWO-PHASE CAPILLARY PUMPED FLIGHT EXPERIMENT
D. R. CHALMERS, J. FREDLEY (General Electric Co., Astro-Space Div., Princeton, NJ), J. KU, and E. J. KROLICZEK (OAO Corp., Greenbelt, MD) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 14 p.
(SAE PAPER 881086)

A two-phase capillary pumped system loop (CPL) flight experiment was performed to demonstrate the capability of a capillary pumped system to absorb, transport, control, and reject heat in Space Station application simulation. This experiment was to provide sufficient data for characterization of the CPL system's performance under microgravity and normal environments. The details of the design, analysis, fabrication and test plan of the experiment program are presented. Ground testing verified the predicted heat transport performance. A.A.F.

A89-27883
MATERIAL COMPATIBILITY PROBLEMS FOR AMMONIA SYSTEMS
ELISABETH M. W. PINCHA, BARBARA L. HEIZER, and MICHAEL P. MCHALE (Boeing, Aerospace, Seattle, WA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 8 p.
(SAE PAPER 881087)

Thermal management systems are currently being developed for application on large orbiting platforms, specifically the Space Station. Based upon its thermodynamic properties, ammonia was selected as a working fluid suitable to handle the power and heat rejection requirements of these systems. The Space Station's 30-year design life, minimum maintenance requirement, maximum reliability, and ammonia working fluid have led to new material compatibility issues. Although ammonia is a well understood fluid for ground-based refrigeration uses, it produced some unexpected results when applied to space-based heat transport systems. Author

A89-27898
SOLID/VAPOR ADSORPTION HEAT PUMPS FOR SPACE APPLICATION
SAM V. SHELTON, WILLIAM J. WEPFER, and J. SCOTT PATTON (Georgia Institute of Technology, Atlanta) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 10 p. refs
(SAE PAPER 881107)

A solid/vapor heat pump with its variable temperature and load capabilities is ideal for the thermal and environmental control of space systems. Merits include utilization of safe refrigerants, minimal electric power requirements, and simplicity of components. Heat rejection and cooling is possible over a range of temperatures, and the selection of various refrigerant/absorption pairs enables designs for various applications. This system is being considered for use in the extravehicular mobility units of spacecrews both for maintenance of comfort and waste heat dissipation. A residential testing has proved the feasibility of the solid/vapor concept. A.A.F.

A89-27900
TWO-PHASE AMMONIA THERMAL BUS TESTBED - EXPERIMENTAL RESULTS
M. P. MCHALE, S. D. GOO, J. E. COLEMAN, and G. L. FRANKFURT (Boeing Aerospace, Seattle, WA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 8 p.
(SAE PAPER 881109)

Future large spacecraft, such as the Space Station, will have high power dissipations and long heat transport distances. The combination of these two requirements dictates the need for a new heat transport technology. An ammonia thermal bus (ATB) concept has been developed using two-phase ammonia as the working fluid. Instrumentation and control systems were used to verify system performance, protect personnel and equipment, and run the system. The ATB was robust; thus operating procedures were simple and fault tolerant. Test results demonstrated a maximum heat load of 22 kW, a controllable turndown ratio of 44:1, and the ability to control setpoint temperatures within the range of 30 to 90 F. This paper describes the ammonia thermal bus (ATB), test instrumentation and control, procedures for operating the ATB, and test results. Author

A89-29218#
PROBLEMS OF THERMAL PROTECTION IN SPACE APPLICATIONS [PROBLEMES DE PROTECTION THERMIQUE DANS LES APPLICATIONS SPATIALES]
J. F. STOHR (ONERA, Chatillon-sous-Bagneux, France) (Societe Francaise des Thermiciens, Journee d'Etudes, Paris, France, Apr. 20, 1988) ONERA, TP, no. 1988-36, 1988, 10 p. In French.
(ONERA, TP NO. 1988-36)

Following a review of the flux and temperature conditions encountered by the Hermes vehicle upon reentry, means of thermal protection are discussed. Problems posed by the use of the ceramic-ceramic composites required for thermal protection are considered, with special attention given to the deformation mode and high-temperature oxidation behavior of these materials. Problems related to the thermal protection of the cryogenic tanks are also reviewed. R.R.

N89-11146# Oak Ridge National Lab., TN.
AN OVERVIEW OF THE STIRLING ENGINE HEAT PUMP PROGRAM
F. C. CHEN 1988 11 p Presented at the 2nd DOE/ORNL Heat Pump Conference: Research and Development on the Heat Pump for Space Conditioning Applications, Washington, D.C., 17 Apr. 1988
(Contract DE-AC05-84OR-21400)
(DE88-013833; CONF-8804100-21) Avail: NTIS HC A03

The paper summarizes the recent developments in the Stirling engine-driven heat pump program activities sponsored by the Department of Energy (DOE) through Oak Ridge National Laboratory (ORNL). This technology has displayed its ability to meet the thermal performance objectives. Enhanced technology options guided by value engineering principles are being pursued toward the development of an economically viable household engine-driven heat pump. DOE

N89-12602*# Analytic Sciences Corp., Washington, DC.
THERMAL/STRUCTURAL DESIGN VERIFICATION STRATEGIES FOR LARGE SPACE STRUCTURES
DAVID BENTON *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 241-252 1988
Avail: NTIS HC A21/MF A01 CSCL 22/2

Requirements for space structures of increasing size, complexity, and precision have engendered a search for thermal design verification methods that do not impose unreasonable costs, that fit within the capabilities of existing facilities, and that still adequately reduce technical risk. This requires a combination of analytical and testing methods. This requires two approaches. The first is to limit thermal testing to sub-elements of the total system only in a compact configuration (i.e., not fully deployed). The second approach is to use a simplified environment to correlate analytical models with test results. These models can then be used to predict flight performance. In practice, a combination of these approaches is needed to verify the thermal/structural design of future very large space systems. Author

N89-12603*# Aeritalia S.p.A., Turin (Italy). Space Systems Group.
IRIS THERMAL BALANCE TEST WITHIN ESTEC LSS
PIERO MESSIDORO, MARINO BALLESIO, and J. P. VESSAZ (European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands) *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 253-267 1988
Avail: NTIS HC A21/MF A01 CSCL 14/2

The Italian Research Interim Stage (IRIS) thermal balance test was successfully performed in the ESTEC Large Space Simulator (LSS) to qualify the thermal design and to validate the thermal mathematical model. Characteristics of the test were the complexity of the set-up required to simulate the Shuttle cargo bay and allowing IRIS mechanism actioning and operation for the first time in the new LSS facility. Details of the test are presented, and test results for IRIS and the LSS facility are described. Author

N89-12613*# Selenia Spazio S.p.A., Rome (Italy).
THE SOLAR SIMULATION TEST OF THE ITALSAT THERMAL STRUCTURAL MODEL Abstract Only
M. GIOMMI, S. LIVERANI, and G. P. SANTIN *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 395-396 1988
Avail: NTIS HC A21/MF A01 CSCL 22/2

The ITALSAT structural/thermal model (STM) was submitted to a solar simulation test in order to verify the spacecraft thermal design and the thermal mathematical model which will be used to predict the on orbit temperatures. The STM was representative of the flight model in terms of configuration, structures, appendages and thermal hardware; dissipating dummy units were used to simulate the electronic units. The test consisted of the main phases: on station (beginning of life), on station (end of life), and transfer orbit. Preliminary results indicate that the test performances were satisfactory. The spacecraft measured temperatures were up to 15 degrees higher than the predicted ones. This imposes a careful correlation analysis in order to have reliable flight temperature predictions. Author

N89-12617*# McDonnell-Douglas Corp., Huntington Beach, CA.
COMPARISON OF SULFURIC AND OXALIC ACID ANODIZING FOR PREPARATION OF THERMAL CONTROL COATINGS FOR SPACECRAFT
HUONG G. LE, JOHN M. WATCHER, and CHARLES A. SMITH *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 437-451 1988
Avail: NTIS HC A21/MF A01 CSCL 22/2

The development of thermal control surfaces, which maintain stable solar absorptivity and infrared emissivity over long periods, is challenging due to severe conditions in low-Earth orbit (LEO). Some candidate coatings are second-surface silver-coated Teflon; second-surface, silvered optical solar reflectors made of glass or quartz; and anodized aluminum. Sulfuric acid anodized and oxalic acid anodized aluminum was evaluated under simulated LEO conditions. Oxalic acid anodizing shows promise of greater stability in LEO over long missions, such as the 30 years planned for the Space Station. However, sulfuric acid anodizing shows lower solar absorptivity. Author

N89-12662# Ebasco Services, Inc., New York, NY.
A MULTIMEGAWATT SPACE POWER SOURCE RADIATOR DESIGN
JACEK JEDRUCH 28 Jan. 1988 19 p Presented at the 5th Symposium on Space Nuclear Power Systems, Albuquerque, N. Mex., 11 Jan. 1988
(Contract DE-AC07-76ID-01570)
(DE88-015185; EGG-M-38487; CONF-880122-17) Avail: NTIS HC A03/MF A01

The multimegawatt space power sources (MMSPS) proposed for deployment in the late 1990s to meet mission burst power requirements, require an increase by four orders of magnitude in the power rating of equipment currently used in space. Prenger and Sullivan (1982) describe various radiator concepts proposed for such applications. They range from the innovative liquid droplet radiator (Mattick and Hertzberg 1981) to the more conventional heat pipe concept (Girrens 1982). The present paper deals with the design of the radiator for one such system, characterized by both high temperature and high pressure. It provides an estimate of the size, mass, and problems of orbiting such a radiator, based on the assumption that the next generation of heavy launch vehicle with 120-tonne carrying capacity, and 4000-cu m cargo volume, will be available for putting hardware into orbit. DOE

N89-13731*# Grumman Aerospace Corp., Bethpage, NY. Space Systems Div.
SOLAR DYNAMIC HEAT REJECTION TECHNOLOGY. TASK 1: SYSTEM CONCEPT DEVELOPMENT Final Report
ERIC GUSTAFSON and ALBERT W. CARLSON Jun. 1987 120 p
(Contract NAS3-24665)
(NASA-CR-179618; NAS 1.26:179618) Avail: NTIS HC A06/MF A01 CSCL 20/4

The results are presented of a concept development study of heat rejection systems for Space Station solar dynamic power systems. The heat rejection concepts are based on recent developments in high thermal transport capacity heat pipe radiators. The thermal performance and weights of each of the heat rejection subsystems is addressed in detail, and critical technologies which require development tests and evaluation for successful demonstration are assessed and identified. Baseline and several alternate heat rejection system configurations and optimum designs are developed for both Brayton and Rankine cycles. The thermal performance, mass properties, assembly requirements, reliability, maintenance requirements and life cycle cost are determined for each configuration. A specific design was then selected for each

configuration which represents an optimum design for that configuration. The final recommendations of heat rejection system configuration for either the Brayton or Rankine cycles depend on the priorities established for the evaluation criteria. Author

N89-14069# Pacific Northwest Labs., Richland, WA.
ROTATING SOLID RADIATIVE COOLANT SYSTEM FOR SPACE NUCLEAR REACTORS
W. J. APLEY and A. L. BABB May 1988 7 p Presented at the 24th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Boston, Mass., 11 Jul. 1988
(Contract DE-AC06-76RL-01830)
(DE88-016312; PNL-SA-15433; CONF-880764-4) Avail: NTIS HC A02/MF A01

The RING power system described in this paper is proposed as a primary or emergency heat rejection system for advanced space reactor power applications. The system employs a set of four (4) counter-rotating, 90 degree offset, coolant-carrying rings. The rings (segmented, corrugated, finned, thin-walled pipes, filled with liquid lithium) pass through a cavity heat exchanger and reradiate the absorbed heat to the space environment. DOE

N89-14392* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
CAPILLARY HEAT TRANSPORT AND FLUID MANAGEMENT DEVICE Patent
JAMES W. OWEN, inventor (to NASA) 13 Sep. 1988 9 p Filed 30 Jun. 1987 Supersedes N87-29769 (25 - 24, p 3309)
(NASA-CASE-MFS-28217-1; US-PATENT-4,770,238; US-PATENT-APPL-SN-067844; US-PATENT-CLASS-165-104.26; US-PATENT-CLASS-165-104.14; US-PATENT-CLASS-122-366)
Avail: US Patent and Trademark Office CSCL 20/4

A passive heat transporting and fluid management apparatus including a housing in the form of an extruded body member having flat upper and lower surfaces is disclosed. A main liquid channel and at least two vapor channels extend longitudinally through the housing from a heat input end to a heat output end. The vapor channels have sintered powdered metal fused about the peripheries to form a porous capillary wick structure. A substantial number of liquid arteries extend transversely through the wicks adjacent the respective upper and lower surfaces of the housing, the arteries extending through the wall of the housing between the vapor channels and the main liquid channel and open into the main liquid channel. Liquid from the main channel enters the artery at the heat input end, wets the wick and is vaporized. When the vapor is cooled at the heat output end, the condensed vapor refills the wick and the liquid reenters the main liquid channel.

Official Gazette of the U.S. Patent and Trademark Office

N89-15042*# Arizona Univ., Tucson.
EXPERIMENTAL CONSTRAINTS ON HEATING AND COOLING RATES OF REFRACTORY INCLUSIONS IN THE EARLY SOLAR SYSTEM Abstract Only
W. V. BOYNTON, DRAKE, HILDEBRAND, JONES, LEWIS, TREIMAN, and WARK *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 1 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 03/2

The refractory inclusions in carbonaceous chondrites were the subject of considerable interest since their discovery. These inclusions contain minerals that are predicted to be some of the earliest condensates from the solar nebula, and contain a plethora of isotopic anomalies of unknown origin. Of particular interest are those coarse-grained inclusions that contain refractory metal particles (Fe, Ni, Pt, Ru, Os Ir). Experimental studies of these inclusions in terrestrial laboratories are, however, complicated because the dense particles tend to settle out of a molten or partially molten silicate material. Heating experiments in the Space Station technology and microgravity in order to observe the effects of metal nuggets (which may act as heterogeneous nucleation sites) on nucleation rates in silicate systems and to measure simultaneously the relative volatilization rate of siderophile and lithophile species. Neither experiment is possible in the terrestrial environment. Author

N89-15456*# Washington Univ., Seattle. Aerospace and Energetics Research Program.
BASIC AND APPLIED RESEARCH RELATED TO THE TECHNOLOGY OF SPACE ENERGY CONVERSION SYSTEMS Semiannual Report, 8 Feb. - 8 Aug. 1988
A. HERTZBERG, A. T. MATTICK, and A. P. BRUCKNER 1988 17 p
(Contract NAG1-327)
(NASA-CR-184644; NAS 1.26:184644) Avail: NTIS HC A03/MF A01 CSCL 10/1

The first six months' research effort on the Liquid Droplet Radiator (LDR) focussed on experimental and theoretical studies of radiation by an LDR droplet cloud. Improvements in the diagnostics for the radiation facility have been made which have permitted an accurate experimental test of theoretical predictions of LDR radiation over a wide range of optical depths, using a cloud of Dow silicone oil droplets. In conjunction with these measurements an analysis was made of the evolution of the cylindrical droplet cloud generated by a 2300-hole orifice plate. This analysis indicates that a considerable degree of agglomeration of droplets occurs over the first meter of travel. Theoretical studies have centered on developments of an efficient means of computing the angular scattering distribution from droplets in an LDR droplet cloud, so that a parameter study can be carried out for LDR radiative performance vs fluid optical properties and cloud geometry. Author

N89-17172# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
CAPILLARY PUMPING FOR A TWO PHASE HEAT TRANSPORT SYSTEM
J.-M. BUCHLIN and P. D. TINARI *In its* Modeling and Applications of Transport Phenomena in Porous Media, Volume 2 45 p 1988
Avail: NTIS HC A12/MF A01

It is suggested that capillary pumped heat transport loops could successfully meet the established criteria for at least one of the thermal control components in a man-tended, low Earth orbit, microgravity environment. The design and physics of the capillary pump are introduced. Problem areas such as the condensing radiator, startup/shutdown, noncondensable gas, and preflight testing are identified. An analytical model of the thermal capillary pumping loop is outlined. Experimental work on capillary pumping is reviewed. ESA

N89-18523# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (Germany, F.R.).
ADVANCED THERMAL DESIGN ASSESSMENT STUDY. VOLUME 1: EXECUTIVE SUMMARY
C. GUENASSIA, comp., B. MIEDZA, comp., and R. ROHR, comp Paris, France ESA 1988 21 p Prepared in cooperation with Erno Raumfahrttechnik G.m.b.H., Bremen, Fed. Republic of Germany, and MATRA Espace, Paris-Velizy, France
(Contract ESTEC-6519/85-NL-MA(SC))
(MBB-ATA-RP-ER-046-VOL-1; ESA-CR(P)-2660-VOL-1; ETN-89-93921) Avail: NTIS HC A03/MF A01

Technical and economic advantages of active thermal control of spacecraft were assessed. It is concluded that in designing a spacecraft at lowest system cost, communication and scientific satellites should be considered separately because of the potential high savings in the repeater system of communications spacecraft when constant temperatures can be guaranteed throughout all mission phases. For other types of electronic equipment the savings are considerably less. Savings in this area have to be compared with increases in the thermal control subsystem and in some other areas: differences in power demand and influence on the mass budget by the thermal control subsystem, power subsystem, and the consumables of the propulsion subsystem with impact on the launch cost. The investigations show that systems with fluid or

two-phase loops demand higher effort, but a concept with feedback controlled variable conductance heat pipes employed on a spacecraft leads to a system which is less expensive than existing designs. A cost saving of 9 pct of the platform cost is evaluated for a communications spacecraft compared with the basic passive concept and 14 percent for a EURECA type spacecraft compared with the fluid loop design. ESA

N89-18524# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (Germany, F.R.).
ADVANCED THERMAL DESIGN ASSESSMENT STUDY. VOLUME 2: SYNTHESIS AND RECOMMENDATIONS Final Report
C. GUENASSIA, comp., B. MIEDZA, comp., and R. ROHR, comp. Paris, France ESA 1988 66 p Prepared in cooperation with Erno Raumfahrttechnik G.m.b.H., Bremen, Fed. Republic of Germany, and MATRA Espace, Paris-Velizy, France
(Contract ESTEC-6519/85-NL-MA(SC))
(MBB-ATA-RP-ER-045-VOL-2; ESA-CR(P)-2660-VOL-2; ETN-89-93922) Avail: NTIS HC A04/MF A01

Technical and economic advantages of active thermal control of spacecraft were assessed. It is concluded that in designing a spacecraft at lowest system cost, communication and scientific satellites should be considered separately because of the potential high savings in the repeater system of communications spacecraft when constant temperatures can be guaranteed throughout all mission phases. For other types of electronic equipment the savings are considerably less. Savings in this area have to be compared with increases in the thermal control subsystem and in some other areas: differences in power demand and influence on the mass budget by the thermal control subsystem, power subsystem, and the consumables of the propulsion subsystem with impact on the launch cost. The investigations show that systems with fluid or two-phase loops demand higher effort, but a concept with feedback controlled variable conductance heat pipes employed on a spacecraft leads to a system which is less expensive than existing designs. A cost saving of 9 pct of the platform cost is evaluated for a communications spacecraft compared with the basic passive concept and 14 pct for a EURECA type spacecraft compared with the fluid loop design. ESA

N89-19519# Naval Postgraduate School, Monterey, CA.
TRANSIENT THREE-DIMENSIONAL HEAT CONDUCTION COMPUTATIONS USING BRIAN'S TECHNIQUE M.S. Thesis
JOHN A. WATSON Sep. 1988 208 p
(AD-A201918) Avail: NTIS HC A10/MF A01 CSCL 20/13

A transient three dimensional heat conduction code was developed using finite differences. A stability restriction on the time step was avoided using a technique proposed by Brian. Computations from the code were validated using both the explicit technique and an available closed from solution for small times. The maximum error was found to be within 0.019 percent for an 11 x 11 x 11 grid and time step of 17.117 seconds. The total CPU time to carry out the computations up to 3,600 seconds using Brian's techniques was six times that required for the explicit technique with the same time step of 17.117 seconds. However, as the time step was increased without altering the heometry, the CPU time using Brian's technique decreased and was less than that used in the explicit technique for time steps larger than 110 seconds. The validated code was also used in the analysis of the transient thermal response of a component on an orbiting spacecraft. GRA

05

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS

Includes description of analytical techniques and models, trade studies of technologies, subsystems, support strategies, and experiments for internal and external environmental control and protection, life support systems, human factors, life sciences and safety.

A89-10452
SAFE ASSOCIATION, ANNUAL SYMPOSIUM, 25TH, LAS VEGAS, NV, NOV. 16-19, 1987, PROCEEDINGS
Symposium sponsored by the SAFE Association. Newhall, CA, SAFE Association, 1987, 289 p. For individual items see A89-10453 to A89-10483.
(AD-A199276)

The conference presents papers on the attrition of a molecular sieve in on-board oxygen generating systems, Space Station emergency egress and EVA lighting considerations and candidate Koch hardware, performance criteria for the MSOGS, and an altered control position for simulating fluid shifts during Shuttle launch. Other topics include cognitive workload and symptoms of hypoxia, development of an oxygen mask integrated arterial oxygen saturation (SaO2) monitoring system for pilot protection in advanced fighter aircraft, and eyeblink monitoring as a means of measuring pilot psychological state. Consideration is also given to a new approach to head and neck support, the prediction of Hybrid II manikin head-neck kinematics and dynamics, pyrolaser and optical initiator development, safety in man-machine interfaces, and a passive thermal protection system. K.K.

A89-10504
REGENERATIVE CO2 FIXATION [REGENERATIVE CO2-BINDUNG]
H. PREISS, H. FUNKE, and W. BREITLING (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 129-134. In German. BMFT-supported research.
(DGLR PAPER 87-116)

The current status of regenerative CO2-fixation systems being developed with DFVLR and ESA support for long-term use on the International Space Station is surveyed. The CO2-fixation requirements for a crew of three are outlined; the criteria considered in selecting an ion-exchange-resin solid amine system over cold traps, liquid adsorbers, molecular sieves, and electrochemical cells are indicated; and the results of adsorption, desorption, stability, and cyclic operation tests on a prototype system are presented in extensive graphs and discussed in detail. T.K.

A89-17665#
JEM ECLSS AND MAN SYSTEM
KUNIAKI SHIRAKI, TAKAO YAMAGUCHI (National Space Development Agency of Japan, Tokyo), AKIRA HATTORI, and HIDEKI HAMA (Kawasaki Heavy Industries, Ltd., Kobe, Japan) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 11 p. refs
(IAF PAPER 88-076)

The Japanese Experiment Module (JEM) ECLSS function definition, baseline configuration, and interface with the Space Station core are outlined. The JEM Man System function and subsytems are considered. The ECLSS functional and physical distribution is discussed in terms of the operational and redundancy philosophy of the JEM program. Issues concerning interface with the Space Station include the intermodule ventilation, the CO2 return method, and the atmosphere monitoring system. R.B.

A89-19921*# Southwest Research Inst., San Antonio, TX.
SPACELAB 1 EXPERIMENTS ON INTERACTIONS OF AN ENERGETIC ELECTRON BEAM WITH NEUTRAL GAS
J. A. MARSHALL, C. S. LIN, J. L. BURCH (Southwest Research Institute, San Antonio, TX), T. OBAYASHI (Tokyo, University, Japan), and C. BEGHIN (CNRS, Laboratoire de Physique et Chimie de l'Environnement, Orleans, France) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 25, Sept.-Oct. 1988, p. 361-367. refs
(Contract NAS8-32488; F19628-85-K-0004)

An unusual signature of return current and spacecraft charging potential was observed during the Spacelab 1 mission launched on November 28, 1983. The phenomenon occurred during neutral gas releases from the SEPAC (Space Experiments with Particle Accelerators) magnetoplasma-dynamic arcjet (MPD) concurrent with firings of the PICPAB (Phenomena Induced by Charged Particle Beams) electron gun and was recorded by the instruments of the SEPAC diagnostic package (DGP). Data from the langmuir probe, floating probes, neutral gas pressure gauge, and the plasma wave probes are reported. As the dense neutral gas was released, the return current measured by the langmuir probe changed from positive to negative and a positive potential relative to the spacecraft was measured by the floating probe. The anomalous return current is believed to be attributable to secondary electron fluxes escaping from the spacecraft, and the unusual charging situation is attributed to the formation of a double-layer structure between a hot plasma cloud localized to the MPD and the spacecraft. The charging scenario is supported by a computer simulation. Author

A89-25473#
SOCIAL STRUCTURE AND EFFECTIVENESS IN ISOLATED GROUPS
JEFFREY C. JOHNSON (East Carolina University, Greenville, NC) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0592)

Based on ideas from network or structural analysis, this paper explores the importance of structural heterogeneity, the fit between formal and informal group structure, and the importance of lower status positions and roles in creating effective groups in isolated environments such as space. In addition, this paper suggests how these concepts might aid in the selection and structuring of crews for future missions. Author

A89-26419* California Univ., Davis.
DIFFERENTIAL COLOR BRIGHTNESS AS A BODY ORIENTATION CUE
CHRISTOPHER G. BARBOUR and RICHARD G. COSS (California, University, Davis) Human Factors (ISSN 0018-7208), vol. 30, Dec. 1988, p. 713-717. Research supported by the University of California. refs
(Contract NAG2-428)

Ninety male and female college students reclining on their backs in the dark were disoriented when positioned on a rotating platform under a slowly rotating disk that filled their entire visual field. Half of the disk was painted with a brighter value (about 69 percent higher luminance level) of the color on the other half. The effects of red, blue, and yellow were examined. Subjects wearing frosted goggles viewed the illuminated disk for three rotations. The disk was stopped when the subjects felt that they were right side up. A significant proportion of subjects selected the disk position in which the brighter side of each of the three colors filled their upper visual field. These results suggest that color brightness as well as lighting variation could provide Space Station crew members with body orientation cues as they move around. Author

A89-27802
TWO-BED CARBON MOLECULAR SIEVE CARBON DIOXIDE REMOVAL SYSTEM FEASIBILITY TESTING
R. J. KAY and R. TOM (Allied-Signal Aerospace Co., Torrance, CA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 5 p.
(SAE PAPER 880993)

The regenerable two-bed carbon dioxide removal system, utilizing carbon molecular sieve (CMS), represents a significant advancement over the current Space Station four-bed zeolite molecular sieve baseline system. To demonstrate the feasibility of the CMS system approach, system performance tests were conducted on a two-bed system created by modifying the existing flight-qualified Skylab regenerable carbon dioxide removal system. Results of the performance tests confirmed the two-bed CMS system approach as a viable candidate for Space Station regenerable carbon dioxide removal. Author

A89-27803
STATIC FEED WATER ELECTROLYSIS SYSTEM FOR SPACE STATION OXYGEN AND HYDROGEN GENERATION
FRED A. FORTUNATO, ANDREW J. KOVACH, and LOWELL E. WOLFE (Life Systems, Inc., Cleveland, OH) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p. refs
(SAE PAPER 880994)

An oxygen- and hydrogen-generating water electrolysis system that is being developed for long-term manned operation of the Space Station is described. The system incorporates an alkaline-based oxygen generation assembly (OGA) based on the static feed electrolyzer (SFE) concept. The OGA is expected to provide metabolic oxygen for the crew, to compensate for the O2 lost overboard due to leakage, to supply O2 for airlock repressurization, and to provide hydrogen for reducing CO2 generated in the cabin. The SFE uses highly efficient electrodes with rugged unitized cell construction, integrated mechanical components, and advanced control/monitor instrumentation designed to reduce system complexity while enhancing overall reliability and maintainability. I.S.

A89-27804* Life Systems, Inc., Cleveland, OH.
MATURITY OF THE BOSCH CO2 REDUCTION TECHNOLOGY FOR SPACE STATION APPLICATION
ROBERT C. WAGNER (Life Systems, Inc., Cleveland, OH), ROBYN CARRASQUILLO (NASA, Marshall Space Flight Center, Huntsville, AL), JAMES EDWARDS, and ROY HOLMES (Boeing Aerospace, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p.
(SAE PAPER 880995)

The Bosch process, which catalytically reduces CO2 with H2 to solid carbon and water, is a promising technique for the reduction of the CO2 removed from the Space Station atmosphere and the subsequent water formation for O2 recovery. A Bosch engineering subsystem prototype CO2 reduction unit was developed to demonstrate the feasibility of the Bosch process as a viable technology for Space Station application. A man-rated prototype unit is then described as part of the ECLSS Technology Demonstrator Program. The goal was to develop a Bosch subsystem that not only meets the performance requirements of two 60 person-day carbon cartridge capacities, but also satisfies inherent man-rated requirements such as offgassing characteristics, fail-safe operation, and ease of maintainability. It is concluded that the technology is at a state of maturity directly applicable to flight status for the NASA Space Station program. S.A.V.

A89-27811* Texas Univ., Austin.
ASTRONAUT AND AQUANAUT PERFORMANCE AND ADJUSTMENT BEHAVIORAL ISSUES IN ANALOGOUS ENVIRONMENTS
ROBERT L. HELMREICH, JOHN A. WILHELM (Texas, University, Austin), and H. CLAYTON FOUSHEE (NASA, Ames Research Center, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 8 p. refs
(SAE PAPER 881004)

The utility of analog environments as sources of data for future, long duration space missions is discussed. The undersea habitat is evaluated on a point-by-point basis for similarities and differences

with Space Station and a possible lunar base. The comparability of Antarctic wintering-over stations is also considered. Critical issues for research are described, as well as the requirement that participants be involved in the conduct of meaningful work.
Author

A89-27814* National Aeronautics and Space Administration, Washington, DC.
ADVANCED PHYSICAL-CHEMICAL LIFE SUPPORT SYSTEMS RESEARCH
PEGGY L. EVANICH (NASA, Office of Aeronautics and Space Technology, Washington, DC) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 6 p.
(SAE PAPER 881010)

A proposed NASA space research and technology development program will provide adequate data for designing closed loop life support systems for long-duration manned space missions. This program, referred to as the Pathfinder Physical-Chemical Closed Loop Life Support Program, is to identify and develop critical chemical engineering technologies for the closure of air and water loops within the spacecraft, surface habitats or mobility devices. Computerized simulation can be used both as a research and management tool. Validated models will guide the selection of the best known applicable processes and in the development of new processes. For the integration of the habitat system, a biological subsystem would be introduced to provide food production and to enhance the physical-chemical life support functions on an ever-increasing basis.
A.A.F.

A89-27817* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
AIR AND WATER QUALITY MONITOR ASSESSMENT OF LIFE SUPPORT SUBSYSTEMS
KEN WHITLEY, ROBYN L. CARRASQUILLO, D. HOLDER, and R. HUMPHRIES (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 13 p. refs
(SAE PAPER 881014)

Preprotype air revitalization and water reclamation subsystems (Mole Sieve, Sabatier, Static Feed Electrolyzer, Trace Contaminant Control, and Thermoelectric Integrated Membrane Evaporative Subsystem) were operated and tested independently and in an integrated arrangement. During each test, water and/or gas samples were taken from each subsystem so that overall subsystem performance could be determined. The overall test design and objectives for both subsystem and integrated subsystem tests were limited, and no effort was made to meet water or gas specifications. The results of chemical analyses for each of the participating subsystems are presented along with other selected samples which were analyzed for physical properties and microbiologicals.
Author

A89-27818
SPACE STATION WATER RECOVERY TRADE STUDY - PHASE CHANGE TECHNOLOGY
MAX B. GORENSEK (Life Systems, Inc., Cleveland, OH) and DAVID BAER-PECKHAM (Boeing Aerospace, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 15 p. refs
(SAE PAPER 881015)

Three different phase-change water recovery technologies are under consideration for use aboard the Space Station: the Air Evaporation Subsystem (AES), the Thermoelectric Integrated Membrane Evaporation Subsystem (TIMES), and the Vapor Compression Distillation Subsystem (VCDS). Although each uses evaporation to recover water from wastes, each differs in the way in which the liquid/vapor interface is maintained in zero-gravity, and in the way in which the latent heat is recovered. The potential application of these technologies to each of the five separate water recovery reprocessing loops aboard the Space Station is considered. Comparisons are drawn for urine processing based on a range of evaluation criteria. The VCDS was found to be the most cost-effective method for water reclamation from urine. Recommendations are made for also applying the VCDS to crew hygiene water, animal cage wash water, and experiment waste water processing.
S.A.V.

A89-27819
A STERILE WATER FOR INJECTION SYSTEM (SWIS) FOR USE IN THE PRODUCTION OF RESUSCITATIVE FLUIDS ABOARD THE SPACE STATION
MATHEW J. DUNLEAVY and ANIL D. JHA (Sterimatics Corp., Bedford, MA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 14 p.
(SAE PAPER 881016)

A disposable cartridge is being developed as part of a medical supply weight-reduction alternative for the Health Maintenance Facility of the Space Station. The Sterile Water for Injection System (SWIS) produces intravenous solutions to USP XXI(1) Water for Injection (WFI) quality from available potable water supplies aboard the Space Station, rather than launch the bulk liquids into space. The cartridge will be a passive disposable device, requiring only tap pressure as the driving force for filtration. This paper presents performance data on removal capabilities for specific contaminants, namely, residual halogen (disinfectant, iodine), total dissolved solids, total organic carbon, bacteria, and bacterial endotoxin. In addition, design features of the cartridge are discussed. The SWIS cartridge will weigh approximately 2 kg and have a production capacity of at least 6 kg of WFI at a flow rate of 6 liters/hr.
S.A.V.

A89-27820
USING FLIGHT HARDWARE TO TEST THE SPACE STATION WATER RECLAMATION AND MANAGEMENT SUBSYSTEM IN ZERO-G
DAVID E. WILLIAMS (Rockwell Shuttle Operations Co., Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 6 p. refs
(SAE PAPER 881018)

With the coming of the U.S. Space Station, the testing of the water reclamation system in zero-g could become very important to avoid costly redesigns and logistic problems. This paper outlines one possible way to test the potable water reclamation system as a spacelab payload and the hygiene water reclamation system as a middeck payload in zero-g, while using existing National Space Transportation System flight hardware.
Author

A89-27821
CRITERIA DEFINITION AND PERFORMANCE TESTING OF A SPACE STATION EXPERIMENT WATER MANAGEMENT SYSTEM
A. J. HITT, III, R. H. RENFRO, K. F. SCHIEN, and E. STREAMS (McDonnell Douglas Corp., Saint Louis, MO) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 12 p. refs
(SAE PAPER 881019)

Because of the many experiments proposed for the Space Station United States Laboratory (USL) that will require ultrapure water, the need for a water recovery system has become necessary. This high quality water may be produced by a hybrid of new technologies and by water subsystems currently considered for the ECLS on the Space Station. A testing program has been conducted to evaluate the suitability of these currently available water purification technologies for the USL. These water recovery systems are being evaluated based on the permeate water quality. Samples of the permeate and of the concentrated waste solutions are taken during each test and analyzed for endotoxins, microbes, pH, conductivity, and total organic carbon. One of the three candidate water management system concepts being considered, the Thermoelectric Integrated Membrane Evaporator Subsystem, is used as a test bench challenge, and system test performance results are presented.
S.A.V.

A89-27833* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
PRELIMINARY DESIGN OF THE SPACE STATION ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM
J. L. REUTER, L. D. TURNER, and W. R. HUMPHRIES (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 12 p. refs
(SAE PAPER 881031)

This paper outlines the current status of the Space Station Enrivonmental Control and Life Support System (ECLSS). The seven subsystem groups which comprise the ECLSS are identified and their functional descriptions are provided. The impact that the nominal and safe haven operating requirements have on the physical distribution, sizing, and number of ECLSS subsystems is described. The role that the major ECLSS interfaces with other Space Station systems and elements play in the ECLSS design is described. Author

A89-27834
RECOVERY OF SPACE STATION HYGIENE WATER BY MEMBRANE TECHNOLOGY
A. X. SWAMIKANNU, S. S. KULKARNI, E. W. FUNK (Allied-Signal Aerospace Co., Torrance, CA), and R. A. MADSEN (Allied-Signal Aerospace Co., AiResearch Los Angeles Div., Torrance, CA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p. Research sponsored by Boeing Aerospace Co.
(SAE PAPER 881032)

Research efforts on a reverse osmosis membrane-based recovery system for purifying Space Station shower and laundry washwater are described. A systematic study was conducted of the thermal stability of a proprietary membrane at 74 C and 200 psi operating pressure. Experiments were performed on membrane coupons, and performance of the membrane when exposed to anionic, cationic, and nonionic surfactants was established. A preprototype washwater reclamation unit is discussed which was operated with a spiral wound membrane module. The unit was operated continuously for 12.5 days and permeated approximately 2200 gal of water, equivalent to the water requirements of an eight-person crew for 41 days. The unit operated according to design and processed water meeting the NASA hygiene water separation standards. S.A.V.

A89-27835
AN EFFICIENT AIR EVAPORATION URINE PROCESSING SYSTEM FOR SPACE STATION
R. A. MADSEN (Allied-Signal Aerospace Co., AiResearch Los Angeles Div., Torrance, CA) and D. F. PUTNAM (Umpqua Research Co., Myrtle Creek, OR) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 7 p.
(SAE PAPER 881034)

An analysis of an air evaporation urine processing technique is presented as a viable candidate for the Space Station. This enhanced configuration incorporates a recuperator and an R12 heat pump for energy recovery. The air evaporation urine processor distills water from urine by evaporation of water from urine-saturated felt pads, over which air is circulated in a closed loop. Schematic diagrams of the processor are presented, and a parametric cycle analysis is conducted to establish sensitivity to significant variables and select a tentative design point. Comparisons of design configuration calculations are presented for the specific power and input power requirements of simple cycle and recuperated cycle systems. S.A.V.

A89-27836* Rockwell International Corp., Downey, CA.
NODES PACKAGING OPTION FOR SPACE STATION APPLICATION
KENNETH T. SO (Rockwell International Corp., Downey, CA) and JOHN B. HALL, JR. (NASA, Langley Research Center, Hampton, VA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 6 p.
(SAE PAPER 881035)

Space Station nodes packaging analyses are presented relative to moving environmental control and life support system (ECLSS) equipment from the habitability (HAB) module to node 4, in order to provide more living space and privacy for the crew, remove inherently noisy equipment from the crew quarter, retain crew waste collection and processing equipment in one location, and keep objectionable odor away from the living quarters. In addition, options for moving external electronic equipment from the Space Station truss to pressurized node 3 were evaluated in order to reduce the crew extravehicular-activity time required to install and maintain the equipment. Node size considered in this analysis is 3.66 m in diameter and 5.38 m long. The analysis shows that significant external electronic equipment could be relocated from the Space Station truss structure to node 3, and nonlife critical ECLSS HAB module equipment could be moved to node 4. Author

A89-27837* Bend Research, Inc., OR.
DEHUMIDIFICATION VIA MEMBRANE SEPARATION FOR SPACE-BASED APPLICATIONS
JANE KUCERA GIENGER, RODERICK J. RAY (Bend Research, Inc., OR), and CINDA CHULLEN (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 18 p. refs
(SAE PAPER 881037)

The paper describes the development of a membrane-based dehumidification process for space-based applications, such as spacecraft cabins and EVA space suits. Results presented are from: (1) screening tests conducted to determine the efficacy of various membranes to separate water vapor from air, and (2) parametric and long-term tests of membranes operated at conditions that simulate the range of environmental conditions (e.g., temperature and relative humidity) expected in the planned Space Station. Also included in this paper is a discussion of preliminary designs of membrane-based dehumidification processes for the Space Station and EVA space suits. These designs result in compact and energy-efficient systems that offer significant advantages over conventional dehumidification processes. Author

A89-27838* Modar, Inc., Natick, MA.
SUPERCRITICAL WATER OXIDATION - MICROGRAVITY SOLIDS SEPARATION
WILLIAM R. KILLILEA, GLENN T. HONG, KATHLEEN C. SWALLOW, and TERRY B. THOMASON (Modar, Inc., Natick, MA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 14 p. refs
(Contract NAS2-12176)
(SAE PAPER 881038)

This paper discusses the application of supercritical water oxidation (SCWO) waste treatment and water recycling technology to the problem of waste disposal in-long term manned space missions. As inorganic constituents present in the waste are not soluble in supercritical water, they must be removed from the organic-free supercritical fluid reactor effluent. Supercritical water reactor/solids separator designs capable of removing precipitated solids from the process' supercritical fluid in zero- and low- gravity environments are developed and evaluated. Preliminary experiments are then conducted to test the concepts. Feed materials for the experiments are urine, feces, and wipes with the addition of reverse osmosis brine, the rejected portion of processed hygiene water. The solid properties and their influence on the design of several oxidation-reactor/solids-separator configurations under study are presented. S.A.V.

A89-27839* Massachusetts Inst. of Tech., Cambridge.
FUNDAMENTAL KINETICS AND MECHANISTIC PATHWAYS FOR OXIDATION REACTIONS IN SUPERCRITICAL WATER
PAUL A. WEBLEY and JEFFERSON W. TESTER (MIT, Cambridge, MA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p. refs

(Contract NAG9-252)
(SAE PAPER 881039)

Oxidation of the products of human metabolism in supercritical water has been shown to be an efficient way to accomplish the on-board water/waste recycling in future long-term space flights. Studies of the oxidation kinetics of methane to carbon dioxide in supercritical water are presented in this paper in order to enhance the fundamental understanding of the oxidation of human waste compounds in supercritical water. It is concluded that, although the elementary reaction models remain the best hope for simulating oxidation in supercritical water, several modifications to existing mechanisms need to be made to account for the role of water in the reaction mechanism. S.A.V.

A89-27840* Westinghouse Electric Corp., Pittsburgh, PA.
CARBON DIOXIDE ELECTROLYSIS WITH SOLID OXIDE ELECTROLYTE CELLS FOR OXYGEN RECOVERY IN LIFE SUPPORT SYSTEMS
ARNOLD O. ISENBERG (Westinghouse Electric Corp., Pittsburgh, PA) and ROBERT J. CUSICK (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 16 p. refs
(Contract NAS9-17590)
(SAE PAPER 881040)

The direct electrochemical reduction of carbon dioxide (CO2) is achieved without catalysts and at sufficiently high temperatures to avoid carbon formation. The tubular electrolysis cell consists of thin layers of anode, electrolyte, cathode and cell interconnection. The electrolyte is made from yttria-stabilized zirconia which is an oxygen ion conductor at elevated temperatures. Anode and cell interconnection materials are complex oxides and are electronic conductors. The cathode material is a composite metal-ceramic structure. Cell performance characteristics have been determined using varying feed gas compositions and degrees of electrochemical decomposition. Cell test data are used to project the performance of a three-person CO2-electrolysis breadboard system. Author

A89-27841* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
ADVANCEMENTS IN WATER VAPOR ELECTROLYSIS TECHNOLOGY
CINDA CHULLEN (NASA, Johnson Space Center, Houston, TX), DENNIS B. HEPPNER, and MARTIN SUDAR (Life Systems, Inc., Cleveland, OH) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p. refs
(Contract NAS9-17558)
(SAE PAPER 881041)

The paper describes a technology development program whose goal is to develop water vapor electrolysis (WVE) hardware that can be used selectively as localized topping capability in areas of high metabolic activity without oversizing the central air revitalization system on long-duration manned space missions. The WVE will be used primarily to generate O2 for the crew cabin but also to provide partial humidity control by removing water vapor from the cabin atmosphere. The electrochemically based WVE interfaces with cabin air which is controlled in the following ranges: dry bulb temperature of 292 to 300 K; dew point temperature of 278 to 289 K; relative humidity of 25 to 75 percent; and pressure of 101 + or - 1.4 kPa. Design requirements, construction details, and results for both single-cell and multicell module testing are presented, and the preliminary sizing of a multiperson subsystem is discussed. A.A.F.

A89-27842
CARBON DIOXIDE REDUCTION PROCESSES FOR SPACECRAFT ECLSS - A COMPREHENSIVE REVIEW
GARY P. NOYES (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 10 p. refs
(SAE PAPER 881042)

There currently exist three practical processes for reduction of carbon dioxide in manned spacecraft environment control and life support systems. The Sabatier (SCRS) and the Bosch (BCRS) Carbon Dioxide Reduction Subsystems are well known, while the Advanced Carbon Dioxide Reduction Subsystem (ACRS) is more recently developed. In this paper, the physiochemical fundamentals, developmental history, and reactor hardware implementation of these three processes are described. The methodology, data, and results of a logistics trade study of these carbon dioxide reduction processes for manned space mission application are presented and discussed. Author

A89-27847
MANAGEMENT OF MICROORGANISMS IN CELSS PLANT GROWTH SYSTEMS
BERLIN NELSON (North Dakota State University, Fargo) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 6 p. refs
(SAE PAPER 881047)

A primary concern in the design and operation of controlled ecological life support systems (CELSS), which include higher plants for food and oxygen production in manned space stations and long-duration space flights, is maintaining plant health and maximizing plant growth rates. A potential problem for plant growth systems is plant pathogenic microorganisms which are inevitably introduced into the CELSS. This paper discusses four principal methods of managing microorganisms in plant growth systems. They are: (1) the establishment of plant quarantine protocols, (2) effective and rapid sanitation methods, (3) the creation of microbial communities with known microorganisms to act as buffers against undesirable microorganisms, and (4) the compartmentalization of plant growth systems. S.A.V.

A89-27855* Bionetics Corp., Hampton, VA.
ECLS SYSTEMS FOR A LUNAR BASE - A BASELINE AND SOME ALTERNATE CONCEPTS
WARREN D. HYPES (Bionetics Corp., Hampton, VA) and JOHN B. HALL, JR. (NASA, Langley Research Center, Hampton, VA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 13 p. refs
(SAE PAPER 881058)

A baseline ECLS system for a lunar base manned intermittently by four crewmembers and later permanently occupied by eight crewmembers has been designed. A summary of the physical characteristics for the intermittently manned and the continuously manned bases is given. Since Space Station inheritance is a key assumption in the mission models, the ECLS system components are distributed within Space Station modules and nodes. A 'core assembly' concept is then developed to meet the objectives of both phases of the ECLS system. A supplementary study is discussed which assessed tankage requirements, penalties incurred by adding subsystem redundancy and by pressurizing large surface structures, and difficulties imposed by intermittent occupancy. Alternate concepts using lunar-derived oxygen, the gravitational field as a design aid, and a city utility-type ECLS system are also discussed. S.A.V.

A89-27858* Life Systems, Inc., Cleveland, OH.
ELECTROCHEMICALLY REGENERABLE METABOLIC CO2 AND MOISTURE CONTROL SYSTEM FOR AN ADVANCED EMU APPLICATION
M. C. LEE (Life Systems, Inc., Cleveland, OH), P. S. BECKSTROM (Rockwell International Corp., Houston, TX), and R. J. CUSICK (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 13 p. refs
(Contract NAS9-17307)
(SAE PAPER 881061)

Regenerable CO2 and moisture removal techniques that reduce expendables and logistics requirements are needed to sustain people undertaking extravehicular activities for the Space Station. NASA has been investigating ways to advance the Electrochemically Regenerable CO2 and Moisture Absorption (ERCA) technology to replace the nonregenerable solid lithium

hydroxide absorber for the advanced Portable Life Support System (PLSS). The ERCA technology, due to its use of liquid absorbent, has the ability to effectively satisfy the high metabolic CO2 and moisture removal requirements of PLSS applications. This paper defines the ERCA technology concept and its advantages for the PLSS application, reviews breadboard and subscale testdata and presents the results of design concepts for a prototype Absorber Module of improved performance and the physical characteristics of the projected flight hardware. Author

A89-27859* United Technologies Corp., Windsor Locks, CT.
DEVELOPMENT OF AN ADVANCED SOLID AMINE HUMIDITY AND CO2 CONTROL SYSTEM FOR POTENTIAL SPACE STATION EXTRAVEHICULAR ACTIVITY APPLICATION
TIMOTHY A. NALETTE, ROBERT W. BLASER (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT), WESLEY D. COLEMAN (Rockwell International Corp., Space Transportation Systems Div., Downey, CA), and ROBERT J. CUSICK (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 9 p. refs
(SAE PAPER 881062)

A system for removing metabolic carbon dioxide and water vapor from breathing air within a space suit during NASA Space Station EVA is discussed. The solid amine compound used is packed within a water-cooled metal foam matrix heat-exchanger to remove the exothermic heat of chemical reaction. Details of the design of a canister for humidity and carbon dioxide control and performance of the system are presented. A.A.F.

A89-27861* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
HIGH PRESSURE WATER ELECTROLYSIS FOR SPACE STATION EMU RECHARGE
NICK LANCE (NASA, Johnson Space Center, Houston, TX), MICHAEL PUSKAR, LAWRENCE MOULTHROP, and JOHN ZAGAJA (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p.
(SAE PAPER 881064)

A high pressure oxygen recharge system (HPORS), is being developed for application on board the Space Station. This electrolytic system can provide oxygen at up to 6000 psia without a mechanical compressor. The Hamilton standard HPORS based on a solid polymer electrolyte system is an extension of the much larger and succesful 3000 psia system of the U.S. Navy. Cell modules have been successfully tested under conditions beyond which spacecraft may encounter during launch. The control system with double redundancy and mechanical backups for all electronically controlled components is designed to ensure a safe shutdown. A.A.F.

A89-27868
PHYSIOLOGICAL EFFECTS OF REPEATED DECOMPRESSION AND RECENT ADVANCES IN DECOMPRESSION SICKNESS RESEARCH - A REVIEW
PAUL A. FURR (Grumman Corp., Space Systems Div., Bethpage, NY) and WILLIAM J. SEARS (Aerospace Associates, Inc., Saint Louis, MO) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 7 p. refs
(SAE PAPER 881072)

The objective of this paper is to review the intermediate or long-term physiological effects which may develop on spacecrew members who engage in repetitive EVAs and their subsequent effects on EVA performance, with particular concern for future Space Station activities. The potential for decompression sickness (DCS) is further affected by a variety of environmental effects that cause physiological change during exposure to spaceflight. A literature review is then given which outlines the effects of repeated exposure to subatmospheric pressures on DCS symptomatology, with attention given to studies indicating increased susceptibility to DCS and studies indicating no change or decreased susceptibility to DCS. A brief discussion about data as regards metabolic changes that occur during decompression to subatmospheric pressures concludes the paper. S.A.V.

A89-27872
HUMAN FACTORS IN THE DESIGN OF A VARIABLE GRAVITY RESEARCH FACILITY
BARRY TILLMAN SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 13 p. Research supported by Lockheed Missiles and Space Co. refs
(SAE PAPER 881076)

NASA is considering a space-based variable gravity research facility (VGRF) to study the biomedical effects and habitability of various gravity levels encountered as humans venture from earth. This paper identifies the human factors in the design and use of the VGRF. This includes both the human studies that should be conducted in the VGRF and the design of the VGRF for human habitation. Designers must consider human factors early in the VGRF development to ensure its success. Author

A89-27873* Aquanautics Corp., Emeryville, CA.
OXYGEN EXTRACTION FOR A MISSION LIFE SUPPORT
STEVEN J. CARNEVALE and ANWYL MCDONALD (Aquanautics Corp., Emeryville, CA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 8 p. Research supported by NASA.
(SAE PAPER 881077)

Research conducted to extract oxygen from air or water with possible applications to oxygen production on Mars, the moon, or the Space Station is discussed. The technology under development involves an electrochemical process which is energy-efficient, regenerative and, in combination with a fuel cell, will provide net positive power, and generate oxygen for life support systems. The history of chemical oxygen separation and details of the oxygen separation technology are presented. A.A.F.

A89-27874* Midwest Research Inst., Golden, CO.
SYNTHESIS AND EVALUATION OF ELECTROACTIVE CO2 CARRIERS
W. L. BELL, A. MIEDANER, J. C. SMART, D. L. DUBOIS (Solar Energy Research Institute, Golden, CO), and C. E. VEROSTKO (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p. refs
(Contract NASA ORDER T-5985-M)
(SAE PAPER 881078)

The development of redox CO2 carrier molecules capable of binding CO2 and releasing it will provide a basis for efficient CO2 removal system for possible applications on long-duration manned space missions. The objective of research being conducted is the utilization of these carriers to develop membranes to selectively and efficiently pump CO2 when a potential is applied across the membranes. The topics covered include the effects of pumping rate and CO2 solubility on carrier efficiency, chemical requirements of redox active carriers, and the screening and evaluation of potential carriers. A.A.F.

A89-27878
ELECTROCHEMICAL MULTIGAS SENSORS FOR AIR MONITORING ASSEMBLY
H. V. VENKATASETTY (Honeywell, Inc., Bloomington, MN) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 8 p. refs
(SAE PAPER 881082)

A new class of electrochemical gas sensors based on nonaqueous electrolytes has been developed. Sensors with three electrode configuration and gold sensing electrodes have been fabricated and used for monitoring both carbon dioxide and oxygen with the capability to monitor water vapor using linear scanning voltammetry. Sensors with platinum sensing electrodes have been used to monitor low concentrations of toxic gases such as carbon monoxide and nitrogen oxides with potential capability to monitor organic contaminants. Experimental results obtained with these

low-power and microprocessor-based sensors are presented. The advantages of nonaqueous electrolyte-based sensors over the conventional aqueous-based sensors and semiconductor sensors are discussed in terms of multigas sensing capability, selectivity, sensitivity, stability, and operating life. Author

A89-27886* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE RECOVERY AND UTILIZATION OF SPACE SUIT RANGE-OF-MOTION DATA
AL REINHARDT (NASA, Ames Research Center, Moffett Field, CA) and JAMES S. WALTON SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 9 p. refs
(SAE PAPER 881091)

A technique for recovering data for the range of motion of a subject wearing a space suit is described along with the validation of this technique on an EVA space suit. Digitized data are automatically acquired from video images of the subject; three-dimensional trajectories are recovered from these data, and can be displayed using three-dimensional computer graphics. Target locations are recovered using a unique video processor and close-range photogrammetry. It is concluded that such data can be used in such applications as the animation of anthropometric computer models. A.A.F.

A89-27887* Sterling Software, Palo Alto, CA.
MEASUREMENT OF METABOLIC RESPONSES TO AN ORBITAL-EXTRAVEHICULAR WORK-SIMULATION EXERCISE
RENEE LANTZ (Sterling Software, Inc., Palo Alto, CA) and BRUCE WEBBON (NASA, Ames Research Center, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p. refs
(SAE PAPER 881092)

This paper describes a new system designed to simulate orbital EVA work and measure metabolic responses to these space-work exercises. The system incorporates an experimental protocol, a controlled-atmosphere chamber, an EVA-work exercise device, the instrumentation, and a data acquisition system. Engineering issues associated with the design of the proposed system are discussed. This EVA-work simulating system can be used with various types of upper-body work, including task boards, rope pulling, and arm ergometry. Design diagrams and diagrams of various types of work simulation are included. I.S.

A89-27888
ATMOSPHERIC CONTAMINANT MONITORING AND CONTROL IN AN ENCLOSED ENVIRONMENT
JAMES A. STRACK (General Dynamics Corp., Saint Louis, MO) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 16 p.
(SAE PAPER 881094)

The potential sources of airborne atmospheric contaminants of an enclosed environment are discussed. The types of the contaminants and wastes specific for enclosed environments of different types, such as a submarine, aircraft, and spacecraft, are examined, and the limits of their potentially toxic levels are given. Instruments used to monitor the concentrations of various atmospheric gases are described. Various methods available for the control of environmental contaminants are described, including methods for the removal of CO2, CO, aerosols, odors, and airborne particulates. I.S.

A89-27893* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
DEVELOPMENT OF THE NASA ZPS MARK III 57.2-KN/SQ M (8.3 PSI) SPACE SUIT
JOSEPH J. KOSMO, WILLIAM E. SPENNY (NASA, Johnson Space Center, Houston, TX), ROB GRAY, and PHIL SPAMPINATO (ILC Dover, Frederica, DE) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 23 p.
(SAE PAPER 881101)

The zero-prebreathe Mark III, 8.3-psi EVA-capable space-suit assembly represents a significant evolutionary development stage toward the creation of an operational space-suit system for the NASA Space Station Program. The unique implementation of the Ortman cable coupling arrangement allows rapid assembly and disassembly of major suit component hardware; this will in turn facilitate on-orbit maintainability and resizing operations. Advanced thermal/micrometeoroid garment-type protection features were investigated in anticipation of Space Station construction-related EVA hazards, and duly incorporated in the final Mark III suit design. O.C.

A89-27894* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
DEVELOPMENT OF HIGHER OPERATING PRESSURE EXTRAVEHICULAR SPACE-SUIT GLOVE ASSEMBLIES
JOSEPH J. KOSMO (NASA, Johnson Space Center, Houston, TX), JOHN BASSICK (David Clark Co., Inc., Worcester, MA), and KIM PORTER (ILC Dover, Frederica, DE) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 14 p.
(SAE PAPER 881102)

Longer space flights and the advent of extravehicular (EV) operations required drastic improvements in the areas of comfort and mobility, and the incorporation of an EV-hazards protective coverlayer. The current advanced glove designs represent a series of evolutionary engineering efforts aimed at systematically improving higher operating pressure EV glove performance capabilities. Glove design complexity increases with the differential pressure between the glove and the vacuum of space and with the EV activity mobility task requirements. Current space-suit glove design activities associated with the development of candidate higher operating pressure (57.2 kN/sq m) glove assemblies are described. Author

A89-27895* Grumman Aerospace Corp., Bethpage, NY.
THE DEVELOPMENT OF A TEST METHODOLOGY FOR THE EVALUATION OF EVA GLOVES
JOHN M. O'HARA (Grumman Space Systems, Bethpage, NY), JOHN CLELAND, and DAN WINFIELD (Research Triangle Institute, Research Triangle Park, NC) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p. refs
(Contract NAS9-17702)
(SAE PAPER 881103)

This paper describes the development of a standardized set of tests designed to assess EVA-gloved hand capabilities in six measurement domains: range of motion, strength, tactile perception, dexterity, fatigue, and comfort. Based upon an assessment of general human-hand functioning and EVA task requirements, several tests within each measurement domain were developed to provide a comprehensive evaluation. All tests were designed to be conducted in a glove box with the bare hand as a baseline and the EVA glove at operating pressure. Author

A89-27903
AIR REVITALIZATION SYSTEM STUDY FOR JAPANESE SPACE STATION
K. OTSUJI, O. HANABUSA, T. ETOH, and M. MINEMOTO (Mitsubishi Heavy Industries, Ltd., Tokyo, Japan) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 10 p. refs
(SAE PAPER 881112)

An Environment Control and Life Support System (ECLSS) includes such functions as temperature control, humidity control, pressure control, air circulation, carbon dioxide removal and concentration, carbon dioxide reduction and oxygen generation, and contamination control. The first Japanese space habitable system called JEM (Japanese Experimental Module) will be operated by being attached to the U.S. Space Station. This paper describes recent study achievements in key technologies necessary to establish air revitalization system of the ECLSS for the future Japanese space station. Author

A89-27904
AIR REVITALIZATION SYSTEM FOR JAPANESE EXPERIMENT MODULE
Y. YOSHIMURA, K. MANABE (National Space Development Agency of Japan, Tokyo), H. YAMASHIRO, Y. HORIE, S. FUJITA (Kawasaki Heavy Industries, Ltd., Kobe, Japan) et al. SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 9 p. refs
(SAE PAPER 881113)

It is necessary to remove carbon dioxide (CO2) and other contaminant gases generated from the crew and nonmetallic materials to keep the allowable level of them for the long duration life support in the Space Station. Therefore, the Air Revitalization System (ARS) shall be provided in the Space Station. The ARS for Japanese Experiment Module (JEM) consists of a regenerative CO2 removal system and a trace contaminant control system (TCCS). A solid amine CO2 removal system has been evaluated as the preferable technology. An adsorption and catalytic oxidizing method has been selected for the TCCS. This paper outlines the investigations and study results of the ARS for JEM implemented as part of the phase B preliminary study. Author

A89-27905
EUROPEAN ECLS TECHNOLOGY PROGRAMME
CHRIS SAVAGE (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) and HELMUT PREISS (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 9 p.
(SAE PAPER 881114)

The scenarios of ECLSS which will be necessary within the next sixty years are outlined. From this, the need for technologies are derived and condensed in a program plan. Technologies necessary for the Columbus IOC are already under development. The status of this program, which includes the development of regenerative CO2 control, condensing heat exchanger, a contamination control, and a low noise variable speed fan, is described. The areas where the technological development should start immediately are discussed. Author

A89-27908
STUDY OF TRACE CONTAMINANT CONTROL SYSTEM FOR SPACE STATION
Y. YOSHIMURA, K. MANABE (National Space Development Agency of Japan, Tokyo), N. KAMISHIMA, M. MINEMOTO, S. HATANO (Mitsubishi Heavy Industries, Ltd., Tokyo, Japan) et al. SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 12 p. refs
(SAE PAPER 881117)

Since the Space Station will operate in a closed environment over long periods of time, it is essential to develop technologies to control trace contaminants produced by the metabolism of the crew and by the materials from which it is made. In order to accomplish this objective, a combination of adsorption and catalytic oxidation was selected as the technology to control these trace contaminants. Results are reported from adsorption experiments, catalytic oxidation experiments, and experiments to determine the effect on the catalyst capabilities of silicon and halogen constituents, which are thought to be catalytic poisons. Author

A89-27916* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
TESTING OF MATERIALS FOR PASSIVE THERMAL CONTROL OF SPACE SUITS
BERNADETTE SQUIRE (NASA, Ames Research Center, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 14 p. refs
(SAE PAPER 881125)

An effort is underway to determine the coating material of choice for the AX-5 prototype hard space suit. Samples of 6061 aluminum have been coated with one of 10 selected metal coatings, and subjected to corrosion, abrasion, and thermal testing. Changes in reflectance after exposure are documented. Plated gold exhibited minimal degradation of optical properties. A computer model is used in evaluating coating thermal performance in the EVA environment. The model is verified with an experiment designed to measure the heat transfer characteristics of coated space suit parts in a thermal vacuum chamber. Details of this experiment are presented. Author

A89-30991* Tracor Sciences and Systems, Austin, TX.
FEASIBILITY OF VIBRATION MONITORING OF SMALL ROTATING MACHINES FOR THE ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS (ECLSS) OF THE NASA ADVANCED SPACE CRAFT
G. MARTIN MILNER, MIKE BLACK, MIKE HOVENGA, PAUL MCCLURE (Tracor Applied Sciences, Inc., Austin, TX), and PATRICE MILLER (NASA, Johnson Space Center, Houston, TX) IN: Detection, diagnosis and prognosis of rotating machinery to improve reliability, maintainability, and readiness through the application of new and innovative techniques. Cambridge and New York, Cambridge University Press, 1988, p. 249-261. refs

The application of vibration monitoring to the rotating machinery typical of ECLSS components in advanced NASA spacecraft was studied. It is found that the weighted summation of the accelerometer power spectrum is the most successful detection scheme for a majority of problem types. Other detection schemes studied included high-frequency demodulation, cepstrum, clustering, and amplitude processing. K.K.

N89-10184*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
RECHARGEABLE METAL HYDRIDES FOR SPACECRAFT APPLICATION
J. L. PERRY Sep. 1988 37 p
(NASA-TM-4076; M-598; NAS 1.15:4076) Avail: NTIS HC A03/MF A01 CSCL 21I

Storing hydrogen on board the Space Station presents both safety and logistics problems. Conventional storage using pressurized bottles requires large masses, pressures, and volumes to handle the hydrogen to be used in experiments in the U.S. Laboratory Module and residual hydrogen generated by the ECLSS. Rechargeable metal hydrides may be competitive with conventional storage techniques. The basic theory of hydride behavior is presented and the engineering properties of LaNi5 are discussed to gain a clear understanding of the potential of metal hydrides for handling spacecraft hydrogen resources. Applications to Space Station and the safety of metal hydrides are presented and compared to conventional hydride storage. This comparison indicates that metal hydrides may be safer and require lower pressures, less volume, and less mass to store an equivalent mass of hydrogen. Author

N89-12206*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
HAZARDS PROTECTION FOR SPACE SUITS AND SPACECRAFT Patent Application
JOSEPH J. KOSMO, inventor (to NASA) and FREDERICK S. DAWN, inventor (to NASA) 30 Jun. 1988 16 p
(NASA-CASE-MSC-21366-1; NAS 1.71:MSC-21366-1; US-PATENT-APPL-SN-213880) Avail: NTIS HC A03/MF A01 CSCL 06/11

A flexible multi-layered covering for protection against the hazards of exposure to the environment of outer space is presented. The covering includes an outer layer section comprising an outmost lamina of woven expanded tetrafluorethylene yarns (Gore-Tex) for protecting against abrasion and tearing, an underlying weave of meta-aramid yarns (Nomex) and para-aramid yarns (Kevlar) for particle impact protection, an electrostatic charge dissipation and control system incoporated therein, and a chemical contaminants control barrier applied as a coating. A middle section includes a succession of thermal insulating layers of polymeric thermoplastic or thermoforming material, each of which is coated with a metal deposit of high infrared emissivity and low solar radiation absorption characteristics and separated from adjacent insulating layers by a low thermal conductance material. The

covering includes a radiation attenuating layer of a tungsten-loaded polymeric elastomer binder for protecting against bremsstrahlung radiation and an inner layer of rip-stop polyester material for abrasion protection. A chloroprene coating may be supplied by polyester-material for added micrometeroid protection. Securing the means of low heat conductance material secures the multi-layers together as a laminar composite. NASA

N89-12207*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A SURVEY OF SOME REGENERATIVE PHYSICO-CHEMICAL LIFE SUPPORT TECHNOLOGY
THEODORE WYDEVEN Nov. 1988 43 p
(NASA-TM-101004; A-88189; NAS 1.15:101004) Avail: NTIS HC A03/MF A01 CSCL 06/11

To date, manned spaceflight has used the relatively simple support methodology of bringing all the necessary water, oxygen, and food for the duration of the mission, and collecting and storing waste products for return to Earth. This is referred to as an open system. It was recognized early, as manned missions became longer and crew size increased, that the weight, volume, and transportation penalties of storing or routinely resupplying consumables would at some point become too expensive. Since the early 1960's regenerative ECLSS technology has been under development, and there now exists a foundation in both systems definition and subsystem technology to support long-duration manned missions. In many cases this development has reached the engineering prototype stage for physico-chemical subsystems and in this article some of these subsystems are described. Emphasis is placed on physico-chemical waste conversion and related processes which provide sustenance and not on environmental factors or subsystems, e.g., temperature and humidity control, spacecraft architecture, lighting, etc. Author

N89-13885# Naval Health Research Center, San Diego, CA.
A REVIEW OF PSYCHOLOGICAL STUDIES IN THE US ANTARCTIC PROGRAMME Final Report
E. K. ERIC GUNDERSON and LAWRENCE A. PALINKAS 28 Apr. 1988 18 p
(Contract NSF DPP-87-16461)
(AD-A198924; NHRC-88-17) Avail: NTIS HC A03/MF A01 CSCL 05/8

Psychological studies were initiated at U.S. Antarctic stations during the International Geophysical Year of 1957 to 1958. Attitude and symptom questionnaires, supervisor ratings, and sociometric tests were administered to several wintering groups. A more comprehensive program of psychological studies, designed to develop selection criteria for screening Antarctic personnel, was instituted in 1962 by the U.S. Navy. A general concept of individual performance or adjustment emerged from earlier studies that included three essential components: task motivation, emotional stability, and social compatibility. Two methods, supervisor ratings and peer nominations, were used to measure these behavior components, and convergent and discriminant validities were evaluated. Regression equations were then developed to predict each behavior factor for each of three occupational groups, Navy construction personnel, Navy Administrative and technical personnel, and civilian scientists. Recent studies have focused on the impact of wintering-over stresses on long-term health and adjustment of participants. The stressors associated with prolonged isolation in a harsh environment appear to be mediated by personality, environmental, and sociocultural factors. GRA

N89-13889*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
DON/DOFF SUPPORT STAND FOR USE WITH REAR ENTRY SPACE SUITS Patent Application
JOSEPH J. KOSMO, inventor (to NASA), TERRY O. TRI, inventor (to NASA), WILLIAM E. SPENNY, inventor (to NASA), and PHILIP R. WEST, inventor (to NASA) 19 Jul. 1988 22 p
(NASA-CASE-MSC-21364-1; NAS 1.71:MSC-21364-1; US-PATENT-APPL-SN-221472) Avail: NTIS HC A03/MF A01 CSCL 06/11

A don/doff support stand for use with rear entry space suits is disclosed. The support stand is designed for use in one-g environments; however, certain features of the stand can be used on future spacecraft, lunar, or planetary bases. The present invention has a retainer which receives a protrucing lug fixed on the torso section of the space suit. When the lug is locked in the retainer, the space suit is held in a generally upright position. In a one-g environment a portable ladder is positioned adjacent to the rear entry of the space suit supported by the stand. The astronaut climbs up the ladder and grasps a hand bar assembly positioned above the rear entry. The astronaut then slips his legs through the open rear entry and down into the abdominal portion of the suite. The astronaut then lowers himself fully into the suit. The portable ladder is then removed and the astronaut can close the rear entry door. The lug is then disengaged from the retainer and the astronaut is free to engage in training exercises in the suit. When suit use is over, the astronaut returns to the stand and inserts the lug into the retainer. A technician repositions the ladder. The astronaut opens the rear entry door, grasps the hand bar assembly and does a chin-up to extricate himself from the suit. The astronaut climbs down the movable ladder while the suit is supported by the stand. NASA

N89-13893*# Hamilton Standard Div., United Aircraft Corp., Windsor Locks, CT.
MODEL DESCRIPTION DOCUMENT FOR A COMPUTER PROGRAM FOR THE EMULATION/SIMULATION OF A SPACE STATION ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM (ESCM)
JAMES L. YANOSY Sep. 1988 68 p
(Contract NAS1-17397)
(NASA-CR-181737; NAS 1.26:181737; SVHSER-9504) Avail: NTIS HC A04/MF A01 CSCL 05/8

Emulation/Simulation Computer Model (ESCM) computes the transient performance of a Space Station air revitalization subsystem with carbon dioxide removal provided by a solid amine water desorbed subsystem called SAWD. This manual describes the mathematical modeling and equations used in the ESCM. For the system as a whole and for each individual component, the fundamental physical and chemical laws which govern their operations are presented. Assumptions are stated, and when necessary, data is presented to support empirically developed relationships. Author

N89-13894*# Hamilton Standard Div., United Aircraft Corp., Windsor Locks, CT.
UTILITY OF EMULATION AND SIMULATION COMPUTER MODELING OF SPACE STATION ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS
JAMES L. YANOSY Sep. 1988 43 p
(Contract NAS1-17397)
(NASA-CR-181739; NAS 1.26:181739; SVHSER-10640) Avail: NTIS HC A03/MF A01 CSCL 05/8

Over the years, computer modeling has been used extensively in many disciplines to solve engineering problems. A set of computer program tools is proposed to assist the engineer in the various phases of the Space Station program from technology selection through flight operations. The development and application of emulation and simulation transient performance modeling tools for life support systems are examined. The results of the development and the demonstration of the utility of three computer models are presented. The first model is a detailed computer model (emulation) of a solid amine water desorbed (SAWD) CO2 removal subsystem combined with much less detailed models (simulations) of a cabin, crew, and heat exchangers. This model was used in parallel with the hardware design and test of this CO2 removal subsystem. The second model is a simulation of an air revitalization system combined with a wastewater processing system to demonstrate the capabilities to study subsystem integration. The third model is that of a Space Station total air revitalization system. The station configuration consists of a habitat module, a lab module, two crews, and four connecting nodes. Author

N89-15529*# California Univ., Davis. Dept. of Psychology.
IMPLICATIONS OF PRIVACY NEEDS AND INTERPERSONAL DISTANCING MECHANISMS FOR SPACE STATION DESIGN
ALBERT A. HARRISON, ROBERT SOMMER, NANCY STRUTHERS, and KATHLEEN HOYT Aug. 1988 53 p
(Contract NAG2-357)
(NASA-CR-177500; NAS 1.26:177500) Avail: NTIS HC A04/MF A01 CSCL 05/9

Isolation, confinement, and the characteristics of microgravity will accentuate the need for privacy in the proposed NASA space station, yet limit the mechanism available for achieving it. This study proposes a quantitative model for understanding privacy, interpersonal distancing, and performance, and discusses the practical implications for Space Station design. A review of the relevant literature provided the basis for a database, definitions of physical and psychological distancing, loneliness, and crowding, and a quantitative model of situational privacy. The model defines situational privacy (the match between environment and task), and focuses on interpersonal contact along visual, auditory, olfactory, and tactile dimensions. It involves summing across pairs of crew members, contact dimensions, and time, yet also permits separate analyses of subsets of crew members and contact dimensions. The study concludes that performance will benefit when the type and level of contact afforded by the environment align with that required by the task. The key to achieving this is to design a flexible, definable, and redefinable interior environment that provides occupants with a wide array of options to meet their needs for solitude, limited social interaction, and open group activity. The report presents 49 recommendations in five categories to promote a wide range of privacy options despite the space station's volumetric limitations. Author

N89-15530*# Washington Univ., Seattle. Coll. of Architecture and Urban Planning.
THE QUANTITATIVE MODELLING OF HUMAN SPATIAL HABITABILITY
JAMES A. WISE, CHERLY GEISENDORFER, BEVERLY TIEDJE, DAVID LANTRIP, BRIAN JOHNSON, and GLEN GEISENDORFER Aug. 1988 156 p
(Contract NAG2-346)
(NASA-CR-177501; NAS 1.26:177501) Avail: NTIS HC A08/MF A01 CSCL 05/9

A theoretical model for evaluating human spatial habitability (HuSH) in the proposed U.S. Space Station is developed. Optimizing the fitness of the space station environment for human occupancy will help reduce environmental stress due to long-term isolation and confinement in its small habitable volume. The development of tools that operationalize the behavioral bases of spatial volume for visual kinesthetic, and social logic considerations is suggested. This report further calls for systematic scientific investigations of how much real and how much perceived volume people need in order to function normally and with minimal stress in space-based settings. The theoretical model presented in this report can be applied to any size or shape interior, at any scale of consideration, for the Space Station as a whole to an individual enclosure or work station. Using as a point of departure the Isovist model developed by Dr. Michael Benedikt of the U. of Texas, the report suggests that spatial habitability can become as amenable to careful assessment as engineering and life support concerns. Author

N89-15532*# Washington Univ., Seattle. Dept. of Psychology.
THE HUMAN FACTORS OF COLOR IN ENVIRONMENTAL DESIGN: A CRITICAL REVIEW
LEE ROY BEACH, BARBARA K. WISE, and JAMES A. WISE Aug. 1988 138 p
(Contract NCC2-404)
(NASA-CR-177498; NAS 1.26:177498) Avail: NTIS HC A07/MF A01 CSCL 05/9

The literature on environmental color to enhance habitability in the design of Space Station interiors is reviewed. Some 200 studies were examined to determine the relative contributions of the three dimensions of color (hue, saturation, and brightness or lightness) to responses to environmental colorations. Implications of the study for color usage in novel settings and locales include: (1) There are no hard-wired linkages between environmental colors and particular judgmental or emotional states; (2) Perceptual impressions of color applications can, however, affect experiences and performances in settings; (3) Color behavior studies cannot yet specify an optimal color scheme, but instead must consider differing objectives, the relative importance of each, and design features such as the coordination of geometry, color, texture, etc.; (4) Some color-behavior effects are governed by low-level retinal and limbal mechanisms as well as by cognitive processes; and (5) Colors should first be specified in terms of what they are to do instead of what they are. Some exercise of choice is therefore needed to establish a sense of personal competence in the setting, since color must be ultimately be accepted by the people who are to live with it. Author

N89-15535*# Life Systems, Inc., Cleveland, OH.
ALKALINE STATIC FEED ELECTROLYZER BASED OXYGEN GENERATION SYSTEM Final Report
L. D. NOBLE, A. J. KOVACH, F. A. FORTUNATO, F. H. SCHUBERT, and D. J. GRIGGER Oct. 1988 93 p
(Contract NAS9-17602)
(NASA-CR-172093; NAS 1.26:172093; TR-925-96) Avail: NTIS HC A05/MF A01 CSCL 06/11

In preparation for the future deployment of the Space Station, an R and D program was established to demonstrate integrated operation of an alkaline Water Electrolysis System and a fuel cell as an energy storage device. The program's scope was revised when the Space Station Control Board changed the energy storage baseline for the Space Station. The new scope was aimed at the development of an alkaline Static Feed Electrolyzer for use in an Environmental Control/Life Support System as an oxygen generation system. As a result, the program was divided into two phases. The phase 1 effort was directed at the development of the Static Feed Electrolyzer for application in a Regenerative Fuel Cell System. During this phase, the program emphasized incorporation of the Regenerative Fuel Cell System design requirements into the Static Feed Electrolyzer electrochemical module design and the mechanical components design. The mechanical components included a Pressure Control Assembly, a Water Supply Assembly and a Thermal Control Assembly. These designs were completed through manufacturing drawing during Phase 1. The Phase 2 effort was directed at advancing the Alkaline Static Feed Electrolyzer database for an oxygen generation system. This development was aimed at extending the Static Feed Electrolyzer database in areas which may be encountered from initial fabrication through transportation, storage, launch and eventual Space Station startup. During this Phase, the Program emphasized three major areas: materials evaluation, electrochemical module scaling and performance repeatability and Static Feed Electrolyzer operational definition and characterization. Author

N89-15801*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
DISPOSITION OF RECOMMENDED MODIFICATIONS OF JSC 30426
JAMES F. SPANN, ed. *In its* Space Station Induced Monitoring p 71-76 Nov. 1988
Avail: NTIS HC A05/MF A01 CSCL 22/2

On May 11, 1988 changes and additions to the Space Station External Contamination Control Document JSC 30426 were addressed at length as part of the charter of this workshop. The modifications and disposition thereof are given below in a concise form in order that a clear understanding of the recommendations and current status be presented. The format is that each paragraph under question is given along with the proposed modified paragraph followed by the workshop's disposition. In some cases, a brief explanation of the issue is given prior to the paragraph in question. Author

N89-20071*# Montana State Univ., Bozeman. Dept. of Chemistry.
EVALUATION OF AVAILABLE ANALYTICAL TECHNIQUES FOR MONITORING THE QUALITY OF SPACE STATION POTABLE WATER Final Report
RICHARD D. GEER *In* NASA, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988, Volume 1 15 p Feb. 1989
Avail: NTIS HC A09/MF A01 CSCL 06/11

To assure the quality of potable water (PW) on the Space Station (SS) a number of chemical and physical tests must be conducted routinely. After reviewing the requirements for potable water, both direct and indirect analytical methods are evaluated that could make the required tests and improvements compatible with the Space Station operation. A variety of suggestions are made to improve the analytical techniques for SS operation. The most important recommendations are: (1) the silver/silver chloride electrode (SB) method of removing I sub 2/I (-) biocide from the water, since it may interfere with analytical procedures for PW and also its end uses; (2) the orbital reactor (OR) method of carrying out chemistry and electrochemistry in microgravity by using a disk shaped reactor on an orbital table to impart artificial G force to the contents, allowing solution mixing and separation of gases and liquids; and (3) a simple ultra low volume highly sensitive electrochemical/conductivity detector for use with a capillary zone electrophoresis apparatus. It is also recommended, since several different conductivity and resistance measurements are made during the analysis of PW, that the bipolar pulse measuring circuit be used in all these applications for maximum compatibility and redundancy of equipment. Author

06

DYNAMICS AND CONTROLS

Includes descriptions of analytical techniques and computer codes, trade studies, requirements and descriptions of orbit maintenance systems, rigid and flexible body attitude sensing systems and controls such as momentum wheels and/or propulsive schemes.

A89-11651
DYNAMICS AND CONTROL OF LARGE STRUCTURES; PROCEEDINGS OF THE SIXTH VPI&SU/AIAA SYMPOSIUM, BLACKSBURG, VA, JUNE 29-JULY 1, 1987
L. MEIROVITCH, ED. (Virginia Polytechnic Institute and State University, Blacksburg) Symposium sponsored by the Virginia Polytechnic Institute and State University and AIAA. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, 731 p. For individual items see A89-11652 to A89-11693.

Papers are presented on such topics as robustness optimization for the control of flexible structures, square-root filtering for continuous-time models of large space structures, a survey of decentralized control techniques for large space structures, the evaluation of two identification methods for damage detection in large space trusses, a laboratory facility for flexible structure control experiments, and the stability analysis of large space structure control systems with delayed input. Consideration is also given to the optimal control of large flexible space structures, a modified independent modal space control method for the active control of flexible systems, robots for manipulation in a microgravity environment, and the analysis and test of a space truss foldable hinge. B.J.

A89-11652#
SOME RECENT RESULTS ON ROBUSTNESS OPTIMIZATION FOR CONTROL OF FLEXIBLE STRUCTURES
D. W. REW and J. L. JUNKINS (Texas A & M University, College Station) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 1-16. refs

A novel method is presented for finding control gains which satisfy eigenvalue placement constraints and maximize a measure of closed-loop robustness (minimize the condition number of the closed-loop eigenvectors). Numerical results were obtained for several academic examples and this approach was applied successfully to design a feedback law for the Rapid Retargeting and Precision Pointing (R2P2) experiment. Both analytical and numerical results are presented which demonstrate the application to problems of moderate dimensionality (less than order 12), and some comparisons with existing control design approaches are summarized. Author

A89-11653#
REDUCED-ORDER CONTROL DESIGN VIA THE OPTIMAL PROJECTION APPROACH - A HOMOTOPY ALGORITHM FOR GLOBAL OPTIMALITY
S. RICHTER (Harris Corp., Melbourne, FL) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 17-30. refs
(Contract F49620-86-C-0038)

A homotopy algorithm for solving the optimal projection equations (OPE) is presented. Questions of existence and the number of solutions are also examined. It is shown that the number of stabilizing solutions to the given optimal projection equations can be determined and that all solutions can be computed via a homotopic continuation from a simple problem. For an important special case where the number of inputs or the number of outputs to the system is less than or equal to the dimension of the compensator, there is only one solution to the OPE, thus guaranteeing that the globally optimum reduced order controller can be computed. Author

A89-11654*# PRC Kentron, Inc., Hampton, VA.
DIGITAL ROBUST ACTIVE CONTROL LAW SYNTHESIS FOR LARGE ORDER FLEXIBLE STRUCTURE USING PARAMETER OPTIMIZATION
V. MUKHOPADHYAY (PRC Kentron, Inc., Hampton, VA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 31-44. NASA-supported research. refs

A generic procedure for the parameter optimization of a digital control law for a large-order flexible flight vehicle or large space structure modeled as a sampled data system is presented. A linear quadratic Guassian type cost function was minimized, while satisfying a set of constraints on the steady-state rms values of selected design responses, using a constrained optimization technique to meet multiple design requirements. Analytical expressions for the gradients of the cost function and the design constraints on mean square responses with respect to the control law design variables are presented. B.J.

A89-11655*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
RECURSIVE DYNAMICS OF TOPOLOGICAL TREES OF RIGID BODIES VIA KALMAN FILTERING AND BRYSON-FRAZIER SMOOTHING
G. RODRIGUEZ (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 45-60. refs

The inverse and forward dynamics problems for a set of rigid bodies connected by hinges to form a topological tree are solved by using recursive techniques from linear filtering and smoothing theory. An inward filtering sequence computes a set of constraint moments and forces. This is followed by an outward sequence to determine a corresponding set of angular and linear accelerations.

An inward sequence begins at the tips of all of the terminal bodies of the tree and proceeds inwardly through all of the branches until it reaches the root. Similarly, an outward sequence begins at the root and propagates to all of the tree branches until it reaches the tips of the terminal bodies. The paper also provides an approach to evaluate recursively the composite multibody system inertia matrix and its inverse. Author

A89-11668*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ATTITUDE CONTROL SYSTEM TESTING ON SCOLE
J. SHENHAR, D. SPARKS, JR., J. P. WILLIAMS, and R. C. MONTGOMERY (NASA, Langley Research Center, Hampton, VA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 251-273. refs

This paper presents implementation of two control policies on SCOLE (Space Control Laboratory Experiment), a laboratory apparatus representing an offset-feed antenna attached to the Space Shuttle by a flexible mast. In the first case, the flexible mast was restrained by cables, permitting modeling of SCOLE as a rigid-body. Starting from an arbitrary state, SCOLE was maneuvered to a specified terminal state using rigid-body minimum-time control law. In the second case, the so called single step optimal control (SSOC) theory is applied to suppress vibrations of the flexible mast mounted as a cantilever beam. Based on the SSOC theory, two parameter optimization algorithms were developed. Author

A89-11669*# Florida Univ., Gainesville.
PRACTICAL IMPLEMENTATION ISSUES FOR ACTIVE CONTROL OF LARGE FLEXIBLE STRUCTURES
D. C. ZIMMERMAN (Florida, University, Gainesville) and H. H. CUDNEY (New York, State University, Buffalo) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 275-290. refs
(Contract NGT-33-183-801; NGT-33-183-802)

The effect of quantization due to the finite wordlength of microprocessors, analog-to-digital, and digital-to-analog converters, on the desired control law for large flexible structures is investigated. Additionally, the practical effect of actuator dynamics on the stability and performance of the control law is addressed. Finally, an active control experiment is reported which takes into account and demonstrates some of the previously discussed practical considerations. Author

A89-11670#
EFFICIENCY OF STRUCTURE-CONTROL SYSTEMS
H. OZ, K. FARAG (Ohio State University, Columbus), and V. B. VENKAYYA (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 291-311. refs
(Contract F33615-86-C-3212)

The paper examines a nondimensional measure, called the efficiency, of structure-control system (SCS) performance which has the potential to characterize both quantitatively and qualitatively the designer's ability to deal with some of the problem areas such as the assessment of spillover effects, model order reduction, input configuration, and the interaction between structural and control variables from the SCS point of view. The efficiency of the system is defined as the ratio of two control cost functionals pertinent to the structure-control problem where each functional represents an average control power consumed during the control period. This concept is illustrated by investigating the efficiency of various linear quadratic regulator solutions for the ACOSS-4 tetrahedral truss structure. B.J.

A89-11671*# Howard Univ., Washington, DC.
STABILITY ANALYSIS OF LARGE SPACE STRUCTURE CONTROL SYSTEMS WITH DELAYED INPUT
A. S. S. R. REDDY and P. M. BAINUM (Howard University, Washington, DC) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 313-321. refs
(Contract NSG-1414)

Large space structural systems, due to their inherent flexibility and low mass to area ratio, are represented by large dimensional mathematical models. For implementation of the control laws for such systems a finite amount of time is required to evaluate the control signals; and this time delay may cause instability in the closed loop control system that was previously designed without taking the input delay into consideration. The stability analysis of a simple harmonic oscillator representing the equation of a single mode as a function of delay time is analyzed analytically and verified numerically. The effect of inherent damping on the delay is also analyzed. The control problem with delayed input is also formulated in the discrete time domain. Author

A89-11672*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
OPTIMAL LOCATION OF ACTUATORS FOR CORRECTING DISTORTIONS DUE TO MANUFACTURING ERRORS IN LARGE TRUSS STRUCTURES
R. BURDISSO and R. T. HAFTKA (Virginia Polytechnic Institute and State University, Blacksburg) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 323-342. refs
(Contract NAG1-224)

A continuum approximation to the calculation of the statistical properties of the corrected shape of a beam truss is presented, and results of a comparison with the exact statistical analysis were found to be very good. In addition, the position of the actuators was optimized to minimize the weighted rms of the distortion using the continuum analysis. The optimal design is shown to be 13.6 percent better than a uniform design for a parabolic weighting function. It was also found that actuators located on the beam face elements were more effective than actuators located on the diagonal elements. B.J.

A89-11673*# Ohio State Univ., Columbus.
ADAPTIVE CONTROL TECHNIQUES FOR THE SCOLE CONFIGURATION
K. OSSMAN, S. YURKOVICH, and U. OZGUNER (Ohio State University, Columbus) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 343-358. refs
(Contract NAG1-720)

Two adaptive controllers designed for the Spacecraft Control Laboratory Experiment (SCOLE) at NASA Langley Research Center are discussed. The first controller is an adaptive model following variable structure controller and the second is an indirect LQ adaptive controller. For each technique, the design of the controller is outlined and simulation results are presented. Plans for future studies are also discussed. Author

A89-11676#
AN INVESTIGATION OF THE TIME REQUIRED FOR CONTROL OF STRUCTURES
J. K. BENNIGHOF and R. L. BOUCHER (Texas, University, Austin) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 391-406. refs

The minimum time required for accomplishing rigid-body translation of a flexible structure by means of a finite number of unbounded inputs is investigated. It is found that, for less than a

certain time interval for control, it is not possible to decrease the amount of spillover energy by driving more flexible modes to zero at the end of the control interval when a minimum-effort control strategy is used. This time interval is identified as the minimum time required for control of flexible structures, and it is closely related to the time required for waves to travel through the structure. For one-dimensional second-order systems, the minimum time is equal to the time required for waves to travel between adjacent pairs of actuators. A similar result is found for fourth-order systems. Author

A89-11677#
OPTIMAL CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES USING DISTRIBUTED GYRICITY
C. J. DAMAREN and G. M. T. D'ELEUTERIO (Toronto, University, Downsview, Canada) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 407-422. NSERC-supported research. refs

An optimal formulation for the shape control of flexible spacecraft using gyric actuators is proposed whereby the structure is modeled as a continuum in mass, stiffness, and gyricity (i.e., stored angular momentum). The equations of motion are formulated in continuum form, and the optimal control problem is treated using distributed-parameter concepts. The advantages of the concept of a continuous distribution of gyricity in modeling the dynamics and control of large flexible spacecraft with many control moment gyros is demonstrated by a numerical example. V.L.

A89-11679#
ON A MODAL APPROACH TO THE CONTROL OF DISTRIBUTED PARAMETER SYSTEMS
H. H. E. LEIPHOLZ (Waterloo, University, Canada) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 439-452.
(Contract NSERC-A-7297)

In this paper it is shown that elastic systems may become nonself-adjoint by automatic control. It is also shown that if the control term that causes nonself-adjointness has a range of regularity, the modal approach is applicable to the nonself-adjoint problem within the range of regularity. Finally, it is shown how the range of regularity or a subrange of it can be determined. Author

A89-11683#
DYNAMICS AND CONTROL OF FLEXIBLE ROBOT MANIPULATORS
H. BARUH and S. TADIKONDA (Rutgers University, New Brunswick, NJ) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 529-547. refs

Issues associated with modeling and control of robots with elastic arms are considered. An approach similar to substructure synthesis is used, where each link is first modeled independent of the others. The joint displacements are then used as constraints to synthesize the equations of motion. Three different approaches are discussed for the control design, depending on how much one desires to include the contributions of the elastic behavior. Author

A89-11686#
MODULAR LARGE SPACE STRUCTURES DYNAMIC MODELING WITH NONPERFECT JUNCTIONS
F. B. ZAZZERA, A. E. FINZI, and P. MANTEGAZZA (Milano, Politecnico, Milan, Italy) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 603-618. refs

The dynamics of modular repetitive structures is investigated with emphasis on the effect of structural damping and imperfections in the junctions between successive modules on the dispersion relations. The structural transfer matrix is computed, and the solution of the eigenvalue problem derived from the application of Floquet's theory of partial differential equations with periodic coefficients yields dispersion relations for the structure. It is shown that a periodic structure behaves like a mechanical filter and that junction imperfections can modify the passing and stopping bands but do not eliminate the filtering properties. A control system is proposed which allows the elimination of propagating waves. V.L.

A89-11690*# Massachusetts Inst. of Tech., Cambridge.
ANALYSIS OF LIMIT CYCLES IN CONTROL SYSTEMS FOR JOINT DOMINATED STRUCTURES
M. MERCADAL and W. E. VANDER VELDE (MIT, Cambridge, MA) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 661-680.
(Contract NAG1-126)

An approach to the modeling of limit cycles due to joint nonlinearities in large joint dominated space structures is presented which makes it possible to predict limit cycles and determine their stability. An actively controlled truss structure with nonlinear joints is modeled as a linear system with nonlinear feedback by separating the joint load-displacement characteristics into a linear part, which prevails at large displacements, and a nonlinear part. By replacing the joints by their linear parts, it is possible to perform a standard model decomposition which yields a reduced order linear model. Linear control laws can be easily included into the linear part of the system; nonlinear control laws can be implemented but they must be fed back to the linear model. The modeling approach described here allows straightforward limit cycle analysis. V.L.

A89-11814* Illinois Univ., Urbana.
AUTOMATICALLY RECONFIGURABLE CONTROL FOR RAPID RETARGETING OF FLEXIBLE POINTING SYSTEMS
THOMAS A. W. DWYER, III (Illinois, University, Urbana) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 75-82. Research supported by Lockheed Missiles and Space Co. refs
(Contract NAG1-613)

A reconfigurable nonlinear control system design methodology is proposed to automatically correct computed slew torque commands of space-based pointing systems for the effects of slew-induced structural deformations. The possibility of forcing an elastic structure, such as that of a space-based instrument frame, to deform in a preselected way in response to rapid slews is demonstrated. To accomplish this, a supervisory controller must select a pair of algorithms, one for structural counterexcitation and the other for slew torque correction. It is shown how the reachability and subsequent tracking of the appropriate 'slow manifold', where the control algorithms are valid, can be ensured by a fast tracking loop, with time-varying gain dependent only on the commanded angular acceleration. K.K.

A89-12637 Howard Univ., Washington, DC.
THE OPTIMAL CONTROL OF ORBITING LARGE FLEXIBLE BEAMS WITH DISCRETE-TIME OBSERVATIONAL DATA AND RANDOM MEASUREMENT NOISE
GUANGQIAN XING and PETER M. BAINUM (Howard University, Washington, DC) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 161-183. Research supported by Howard University and NASA. refs
(AAS PAPER 87-418)

The analysis and design of LQR optimal digital controllers and LQG optimal digital controllers and observers are presented for the case of an orbiting long, slender flexible free-free beam system, for which the output are the discrete-time noise-corrupted observational data, and both the overall orientation as well as the

shape of some of the subsystems will be controlled. The effect of the sampling period on the transient response for the LQR problem and relationships between the locations of the controller poles and the locations of observer poles have been studied. The simulations certify the analysis and design of digital optimal controllers and observers. Author

A89-12662* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PIEZOELECTRIC POLYMER-BASED ISOLATION MOUNT FOR ARTICULATED POINTING SYSTEMS ON LARGE FLEXIBLE SPACECRAFT
SAMUEL W. SIRLIN (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 613-627. refs
(AAS PAPER 87-456)

When a pointing system is attached to a large flexible body that is subject to continuous excitation, a mechanical isolator becomes a key element in achieving high performance. An active softmount based on the piezoelectric polymer poly (vinylidene fluoride) is considered here for use in a precision pointing system for Space Station. A finite element model of the softmount is developed and added to simple Space Station and payload models for performance analysis. Both linear frequency domain and nonlinear time domain simulations are carried out in order to demonstrate the wideband disturbance rejection capabilities of the design. Nonlinear geometric effects of large nodal deflections are also considered. Author

A89-12674
DEPLOYMENT, POINTING, AND SPIN OF ACTIVELY-CONTROLLED SPACECRAFT CONTAINING ELASTIC BEAM-LIKE APPENDAGES
R. R. RYAN (Michigan, University, Ann Arbor) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 2. San Diego, CA, Univelt, Inc., 1988, p. 853-876. refs
(AAS PAPER 87-478)

A comprehensive theory and equations of motion are presented for a free-flying rigid body with flexible beamlike appendages. It is shown that, in order to accurately simulate general aerospace structures undergoing large overall motions and small deformations, it is necessary to treat each distinct type of structural element comprising the system in a special way. The advantage of this modal theory over nonlinear finite element techniques is discussed. K.K.

A89-12678
DYNAMICS AND CONTROL ANALYSIS OF A SATELLITE WITH A LARGE FLEXIBLE SPINNING ANTENNA
P. H. MAK, M. M. TONG, and A. B. JENKIN (Aerospace Corp., Control Analysis Dept., El Segundo, CA) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 2. San Diego, CA, Univelt, Inc., 1988, p. 935-951.
(Contract F04701-85-C-0086)
(AAS PAPER 87-482)

A feasibility study was carried out on a low-frequency microwave radiometer (LFMR) with a 20-ft diameter deployable truss antenna spinning asymmetrically at 15.8 rpm onboard a 3-axis stabilized spacecraft for the N-ROSS mission. No significant interactions were observed between the attitude control system and the flexible structures. The attitude pointing requirement can be met if the LFMR is properly balanced. The spin-induced deformation in the flexible structure is indicative of a relatively small sensor boresight pointing error. K.K.

A89-13394#
A RECURSIVE FORMULATION FOR THE DYNAMIC ANALYSIS OF OPEN LOOP DEFORMABLE MULTIBODY SYSTEMS
K. CHANGIZI and A. A. SHABANA (Illinois, University, Chicago) ASME, Transactions, Journal of Applied Mechanics (ISSN 0021-8936), vol. 55, Sept. 1988, p. 687-693. refs
(Contract DAAL03-87-K-0124)
(AD-A203248)

A recursive formulation for the spatial kinematic and dynamic analysis of open chain mechanical systems containing interconnected deformable bodies is proposed. The large rotational and translational displacements of a set of intermediate joint axes are described using a minimum set of relative translational and rotational coordinates. The method can be used to study the spatial dynamics of open loop mechanical systems containing revolute, prismatic, and cylindrical joints. R.R.

A89-16160#
POLE-ZERO MODELING OF FLEXIBLE SPACE STRUCTURES
BONG WIE (Texas, University, Austin) and ARTHUR E. BRYSON, JR. (Stanford University, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 11, Nov.-Dec. 1988, p. 554-561. refs

Generic models of flexible space structures are investigated from the infinite discrete-spectrum viewpoint of distributed parameter systems. The models are simple enough to treat analytically, yet complicated enough to demonstrate the practical usefulness of the transcendental-transfer-function modeling for the purposes of preliminary control synthesis. Transfer functions of the various generic models are derived analytically, and their pole-zero patterns are investigated. The alternating pole-zero pattern of a transfer function from an actuator to the colocated sensor is well known. It is, however, newly found that in certain colocated cases, each mode has an associated zero of higher frequency than the pole; in fact, the rigid-body mode has an associated zero very close to the origin. This direct transmission property must be taken into consideration when designing large space structures such as the dual-keel Space Station, which has a pole-zero pattern very similar to that of the generic models. The practical significance of such pole-zero patterns on colocated control is discussed. Author

A89-16508*# Auburn Univ., AL.
ANALYSIS OF COILS OF WIRE ROPE ARRANGED FOR PASSIVE DAMPING
M. A. CUTCHINS, J. E. COCHRAN, JR., K. KUMAR (Auburn University, AL), N. G. FITZ-COY, and M. L. TINKER International Conference on Recent Advances in Structural Dynamics, 3rd, Southampton, England, July 18-22, 1988, Paper. 12 p. refs
(Contract NAG8-532; NAG8-647)

Vibration dampers constructed with multiple loops of wire rope are studied. The literature on such devices is reviewed briefly, and dynamic and static models of them are examined. Fundamental and advanced NASTRAN models for wire rope damping are considered. C.D.

A89-16709* Ohio State Univ., Columbus.
MODEL REFERENCE, SLIDING MODE ADAPTIVE CONTROL FOR FLEXIBLE STRUCTURES
S. YURKOVICH, U. OZGUNER, and F. AL-ABBASS (Ohio State University, Columbus) Journal of the Astronautical Sciences (ISSN 0021-9142), vol. 36, July-Sept. 1988, p. 285-310. refs
(Contract NASA ORDER L-91188-B)

A decentralized model reference adaptive approach using a variable-structure sliding model control has been developed for the vibration suppression of large flexible structures. Local models are derived based upon the desired damping and response time in a model-following scheme, and variable structure controllers are then designed which employ colocated angular rate and position feedback. Numerical simulations have been performed using NASA's flexible grid experimental apparatus. R.R.

A89-17642#
THE ROLE OF PILOT AND AUTOMATIC ONBOARD SYSTEMS IN FUTURE RENDEZVOUS AND DOCKING OPERATIONS
W. FEHSE, A. TOBIAS (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands), A. GETZSCHMANN

(MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany), M. CALDICHOURY (Matra, S.A., Toulouse, France), P. MAUTE (Aerospatiale, Cannes, France) et al. IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 12 p.
(IAF PAPER 88-037)

The planned European Space Infrastructure with its elements, e.g., the Hermes Spaceplane and the Columbus Man-Tended Free Flyer (MTFF) requires for Europe novel space operations such as rendezvous and docking (RVD) or berthing of manned spacecraft. The European Space Agency (ESA), therefore, decided to investigate the role of a pilot during RVD operations within a highly automated spacecraft. An analysis of requirements, of the tasks to be performed on-board during RVD operations, of the possibilities of interaction by a pilot with an automated Guidance, Navigation and Control (GNC) system, and of the necessary Man-Machine Interfaces (MMI) had to be performed to arrive at first answers to the questions of man-machine interaction in modern spacecraft control. The results of this analysis are presented and discussed for the example of a Hermes mission to service the Columbus MTFF. Proposals for specific MMI displays and their arrangement in the cockpit, which could be useful during rendezvous operations for GNC and mission management are presented. Author

A89-17648#
A FLIGHT EXPERIMENT OF FLEXIBLE SPACECRAFT ATTITUDE CONTROL
T. KIDA, I. YAMAGUCHI, Y. OHKAMI (National Aerospace Laboratory, Chofu, Japan), S. ICHIKAWA, and Y. KAWADA (National Space Development Agency of Japan, Tokyo) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 6 p.
(IAF PAPER 88-044)

Plans for a flight experiment of the flexible spacecraft Engineering Test Satellite VI (ETS-IV) are outlined. The ETS-IV is expected to be launched in 1992. The flight experiment is planned to demonstrate the capabilities of the attitude and flexible vibration control and the indentification algorithm of a class of spacecraft with flexible appendages. It is suggested that the results could serve as a base-line of a class of future large space structures modeling and controlling technology. R.B.

A89-18432
MOTION OF A GRAVITY GRADIENT SATELLITE WITH HYSTERESIS RODS IN A POLAR-ORBIT PLANE [DVIZHENIE GRAVITATSIONNO-ORIENTIROVANNOGO SPUTNIKA S GISTEREZISNYMI STERZHNIAMI V PLOSKOSTI POLIARNOI ORBITY]
V. A. SARYCHEV, V. I. PEN'KOV, M. IU. OVCHINNIKOV, and A. D. GERMAN Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 26, Sept.-Oct. 1988, p. 654-668. In Russian. refs

The small oscillations of a three-axis gravity gradient satellite are analyzed. The energy of its oscillations is dissipated in hysteresis rods as they are magnetized in the geomagnetic field. Various oscillation damping laws depending on the orientation of the rods in the body are obtained. B.J.

A89-18436
DYNAMICS OF A SPACECRAFT WITH DIRECT ACTIVE CONTROL OF THE GRAVITY GRADIENT STABILIZER [DINAMIKA KOSMICHESKOGO APPARATA S PRIAMYM AKTIVNYM UPRAVLENIEM GRAVITATSIONNYM STABILIZATOROM]
E. M. POTAPENKO Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 26, Sept.-Oct. 1988, p. 699-708. In Russian. refs

Equations of spacecraft motion are obtained with allowance for an arbitrary but finite number of tons of elastic oscillations of a controlled gravity gradient stabilizer. A dynamic controller is used to optimize the spacecraft attitude control and stabilization system with allowance for the first tone of the elastic oscillations. B.J.

A89-20582
A COVARIANCE CONTROL THEORY
ANTHONY F. HOTZ and ROBERT E. SKELTON (Purdue University, West Lafayette, IN) IN: Control and dynamic systems. Volume 26. Part 2. San Diego, CA, Academic Press, Inc., 1987, p. 225-276. refs

A theory for designing feedback controllers is developed which assigns a specified covariance to the closed loop system. The theory is restricted to linear time-invariant systems with constant gain state feedback or state-estimate feedback controllers. The principal theorems and a design example are presented. V.L.

A89-20601
ROBOTICS AND FACTORIES OF THE FUTURE '87; PROCEEDINGS OF THE SECOND INTERNATIONAL CONFERENCE, SAN DIEGO, CA, JULY 28-31, 1987
R. RADHARAMANAN, ED. (San Diego State University, CA) Conference sponsored by the International Society for Productivity Enhancement, San Diego State University, U.S. Navy, et al. Berlin and New York, Springer-Verlag, 1988, 862 p. For individual items see A89-20602 to A89-20610.

The conference presents papers on planning of automation, CAD/CAM, CIM/FMS, kinematic analysis, dynamics and control, trajectory planning, and sensors and vision systems. Other topics include AI and expert systems, mobile robots/robotic devices, robot applications, automation and innovation in mining, and CAD/CAM and robotics education/training. Particular attention is given to the use of CAD systems in the design of Space Station and space robots, a kinematic model of flexible robot arms, and a state-of-the-art survey of robot programming languages. K.K.

A89-20607
CONTROLLER DESIGN AND DYNAMIC SIMULATION OF ELASTIC ROBOT ARM MOUNTED IN SPACECRAFT IN PRESENCE OF UNCERTAINTY
SAHJENDRA N. SINGH (Nevada, University, Las Vegas) IN: Robotics and factories of the future '87; Proceedings of the Second International Conference, San Diego, CA, July 28-31, 1987. Berlin and New York, Springer-Verlag, 1988, p. 347-354. refs

The paper presents an approach to the control of an uncertain nonlinear flexible robotic system. A robot arm (PUMA-type) with three rotational joints is considered. The third link is assumed to be elastic. A torquer control law is derived for controlling the joint angles. For damping of the elastic vibration, a force control law using modal velocity feedback is synthesized. Simulation results are presented to show that combination of the torque and force control law accomplishes reference joint angle trajectory tracking and elastic mode stabilization in spite of the uncertainty in the system. Author

A89-20830
GUIDANCE AND CONTROL 1988; PROCEEDINGS OF THE ANNUAL ROCKY MOUNTAIN GUIDANCE AND CONTROL CONFERENCE, KEYSTONE, CO, JAN. 30-FEB. 3, 1988
ROBERT D. CULP, ED. (Colorado, University, Boulder) and PAUL L. SHATTUCK, ED. (Martin Marietta Astronautics Co., Denver, CO) Conference sponsored by AAS. San Diego, CA, Univelt, Inc., 1988, 576 p. For individual items see A89-20831 to A89-20857.

Spacecraft attitude control and autonomy are discussed as well as guidance and control storyboard displays, offboard navigation and attitude systems, Space Station system control techniques, and recent experiences. Topics include an EOS integrated payload articulation and identification, automated low-thrust guidance for the orbital maneuvering vehicle, dithered ring laser gyros for angular rate stabilization of tracking systems, and attitude determination using GPS measurement techniques. Consideration is also given to quiet structures for precision pointing, on-orbit guidance for the Delta 180 mission, and Titan 34D-9 failure investigation and recovery. K.K.

A89-20845
CONTROL MOMENT GYROSCOPE CONFIGURATIONS FOR THE SPACE STATION
MARC MEFFE (Honeywell, Inc., Satellite Systems Div., Glendale,

AZ) IN: Guidance and control 1988; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 30-Feb. 3, 1988. San Diego, CA, Univelt, Inc., 1988, p. 269-292.
(AAS PAPER 88-040)

Thirteen control moment gyroscope (CMG) arrays were analyzed to parametrically determine penalties in weight, power, volume, safety, maintainability, verification requirements, control requirements, and life-cycle costs. One of the single-gimbal CMG arrays provided the best solution for the Space Station's active momentum exchange. When compared on an equal reliability basis, single-gimbal CMG arrays outperformed equivalent double-gimbal arrays. K.K.

A89-20848
OVERVIEW OF SPACE STATION ATTITUDE CONTROL SYSTEM WITH ACTIVE MOMENTUM MANAGEMENT
JOHN A. YEICHNER, JOHN F. L. LEE (Honeywell, Inc., Space and Strategic Div., Clearwater, FL), and DAVE BARROWS (McDonnell Douglas Astronautics Co., Space Station Div., Huntington Beach, CA) IN: Guidance and control 1988; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 30-Feb. 3, 1988. San Diego, CA, Univelt, Inc., 1988, p. 355-372. refs
(AAS PAPER 88-044)

An approach to the development and implementation of the Space Station's attitude control system (ACS) is presented. Problems such as controllability during build-up, multibody flexure stabilization, and attitude control impact during mobile service center operations are addressed. An ACS with an active momentum management system whose design is based on an integrated control moment gyro and reaction-jet control system concept is described. K.K.

A89-20849* Ohio Univ., Athens.
FORMULATION AND VERIFICATION OF FREQUENCY RESPONSE SYSTEM IDENTIFICATION TECHNIQUES FOR LARGE SPACE STRUCTURES
JERREL R. MITCHELL (Ohio University, Athens), VICTORIA L. JONES (Control Dynamics Co., Huntsville, AL), and CHARLES P. PLANT IN: Guidance and control 1988; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 30-Feb. 3, 1988. San Diego, CA, Univelt, Inc., 1988, p. 373-398. refs
(Contract NAS8-35835)
(AAS PAPER 88-045)

The advantages of designing control systems for large space structures (LSS) using frequency-domain models extracted from empirical time data are discussed. Techniques for performing MIMO system identification from test data are presented as well as techniques for improving the performance of the system identification process in the presence of noise. The utility of the proposed system identification scheme is demonstrated on the basis of experimental data obtained at the LSS Ground Test Facility at Marshall Space Flight Center. K.K.

A89-20850
QUIET STRUCTURES FOR PRECISION POINTING
P. A. STUDER (Magnetic Concepts, Silver Spring, MD) and H. W. DAVIS (Ball Corp., Ball Aerospace Systems Div., Boulder, CO) IN: Guidance and control 1988; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 30-Feb. 3, 1988. San Diego, CA, Univelt, Inc., 1988, p. 399-416. refs
(AAS PAPER 88-046)

The feasibility of immediately implementing quiet structures for the Space Station Polar Orbiting Platforms and other generic platform applications is demonstrated. The quiet structure system will provide both distortion control and dynamic control to accommodate a wide range of disturbance frequencies. Challenges to traditional design approaches are discussed with attention given to the shortcomings of flexible spacecraft structures. K.K.

A89-22510#
PLANAR, TIME-OPTIMAL, REST-TO-REST SLEWING MANEUVERS OF FLEXIBLE SPACECRAFT
GURKIRPAL SINGH, PIERRE T. KABAMBA, and N. HARRIS MCCLAMROCH (Michigan, University, Ann Arbor) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Jan.-Feb. 1989, p. 71-81. refs

The control problem of time-optimal, rest-to-rest slewing of a flexible spacecraft through a large angle is considered. The flexible spacecraft is modeled as a linear, elastic, undamped, nongyroscopic system suitable for analysis of planar rotational maneuvers. Minimum-time open-loop planar maneuvers are studied. The control histories are found to be bang-bang with multiple switches in each control variable. The optimal control history is shown to have an important time symmetry property. The switching times, final time, and costates at midmaneuver satisfy a system of nonlinear algebraic equations that can be solved using a homotopy method. An upper bound on attitude error due to control spillover is obtained. This helps to determine, a priori, the number of vibrational modes that need to be actively suppressed at the final time such that a prespecified pointing accuracy is guaranteed after the maneuver has been completed. A time-optimal slewing example is discussed to demonstrate the applicability of the results. Author

A89-22511#
NEAR-MINIMUM TIME OPEN-LOOP SLEWING OF FLEXIBLE VEHICLES
R. C. THOMPSON, J. L. JUNKINS, and S. R. VADALI (Texas A & M University, College Station) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Jan.-Feb. 1989, p. 82-88. refs

Minimum time, open-loop, optimal controls are calculated for single-axis maneuvers of a flexible structure. By shaping the control profiles with two independent parameters, a wide variety of control histories can be produced. Based on the dynamics of the model, with a normalized time scale, the resulting Pontryagin's necessary conditions yield a nonlinear fixed final time, fixed final state, two-point boundary value problem with the maneuver time as a control parameter. Upon generating numerical solutions to the problem, the final maneuver time and residual flexural energy are compared to the bang-bang solution as a measure of the success of a given maneuver. Examples presented illustrate near-minimum time maneuvers with control of flexible modes in addition to the rigid body modes, as well as the qualitative and quantitative effect of the torque shaping parameters. Author

A89-22520*# Massachusetts Inst. of Tech., Cambridge.
SENSOR FAILURE DETECTION USING GENERALIZED PARITY RELATIONS FOR FLEXIBLE STRUCTURES
MATHIEU MERCADAL (MIT, Cambridge, MA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Jan.-Feb. 1989, p. 125-127. refs
(Contract NAG1-126)

Analytical redundancy may be preferable to hardware redundancy in failure detection/isolation tasks for such large-scale systems as space structures. Generalized single-sensor parity relations are presently applied to this problem; they are noted to yield a very simple isolation logic, and their generation is found to be extremely rapid, even in the case of extremely complex systems, provided only that the eigenstructure of the system be known. Their implementation is, however, extremely sensitive to modeling errors and noise. O.C.

A89-24476
AUTOMATIC CONTROL; PROCEEDINGS OF THE TENTH TRIENNIAL WORLD CONGRESS OF IFAC, MUNICH, FEDERAL REPUBLIC OF GERMANY, JULY 27-31, 1987. VOLUME 6
ROLF ISERMANN, ED. (Darmstadt, Technische Hochschule, Federal Republic of Germany) Congress sponsored by IFAC, International Association for Mathematics and Computer Simulation, International Federation for Information Processing, et al . Oxford,

England and Elmsford, NY, Pergamon Press, (IFAC Proceedings Series, No. 11), 1988, 463 p. For individual items see A89-24477 to A89-24506.

Recent advances in control theory and applications are discussed in reviews and reports. Topics addressed include satellite control, satellite attitude control, flight control of airborne vehicles, space stations and platforms, space experiments and control of active optics, and the evolution of simulators for airborne vehicles. Consideration is given to control of ship operations, control of air and ground transportation, expert systems in on-line control, expert systems for diagnosis and performance monitoring, and the use of AI methods for control. T.K.

A89-24482
DECENTRALIZED FREQUENCY SHAPING AND MODAL SENSITIVITIES FOR OPTIMAL CONTROL OF LARGE SPACE STRUCTURES
U. OZGUNER and S. YURKOVICH (Ohio State University, Columbus) IN: Automatic control; Proceedings of the Tenth Triennial World Congress of IFAC, Munich, Federal Republic of Germany, July 27-31, 1987. Volume 6. Oxford, England and Elmsford, NY, Pergamon Press, 1988, p. 43-48. Research supported by the Ohio State University. refs

Methods from the area of decentralized control which have emerged for analysis and control of large flexible space structures are reviewed. Many critical issues remain for consideration in control problems of flexible spacecraft, including the need for incorporation of actuator dynamics in the system model, the need for an initial stabilizing feedback solution to initiate computation in optimal controller design, and the need for inclusion of frequency domain constraints into the state-space formulation. Author

A89-25371#
APPLICATION OF INTEGRATED GN&C SIMULATION AND ANALYSIS TO ADVANCED AEROSPACE VEHICLES
JOHN F. PFLUG, JEFF R. RING, CHRISTOPHER A. MAGILL, and ROGER F. BLOCK (Honeywell, Inc., Space and Strategic Avionics Div., Clearwater, FL) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p.
(AIAA PAPER 89-0454)

The characteristics of simulation and analysis computer aided design tools are discussed. Examples of integrated guidance, navigation, and control analysis methodologies are presented as well as results for a representative Space Station crew escape and return vehicle, a crew emergency return vehicle, and a hypersonic vehicle. It is shown that significant benefits in lower design cost and risk are achievable together with greatly improved productivity for the design team. K.K.

A89-25436*# NASA Space Station Program Office, Reston, VA.
PRELIMINARY CONTROL/STRUCTURE INTERACTION STUDY OF COUPLED SPACE STATION FREEDOM/ASSEMBLY WORK PLATFORM/ORBITER
SUDEEP K. SINGH (Grumman Corp., Grumman Space Station Program Support Div., Reston, VA) and ALAN J. LINDENMOYER (NASA, Space Station Freedom Program Office, Reston, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 15 p. refs
(AIAA PAPER 89-0543)

Results are presented from a preliminary control/structure interaction study of the Space Station, the Assembly Work Platform, and the STS orbiter dynamics coupled with the orbiter and station control systems. The first three Space Station assembly flight configurations and their finite element representations are illustrated. These configurations are compared in terms of control authority in each axis and propellant usage. The control systems design parameters during assembly are computed. Although the rigid body response was acceptable with the orbiter Primary Reaction Control System, the flexible body response showed large structural deflections and loads. It was found that severe control/structure interaction occurred if the stiffness of the Assembly Work Platform was equal to that of the station truss. Also, the response of the orbiter Vernier Reaction Control System to small changes in inertia properties is examined. R.B.

A89-25868* National Science Foundation, Washington, DC.
INTERNATIONAL CONFERENCE ON ADVANCES IN COMMUNICATION AND CONTROL SYSTEMS, 1ST, WASHINGTON, DC, JUNE 18-20, 1987, PROCEEDINGS
NICHOLAS DECLARIS, ED. (NSF, Technologies Div., Washington, DC) Conference sponsored by the International Federation of Information Processing Societies and NASA. New York, Optimization Software, Inc., 1988, 224 p. For individual items see A89-25869 to A89-25875.

Theoretical models of communication and control systems are discussed in reviews and reports. Topics addressed include smoothing and identification for random fields, the information and coding capacities of mismatched Gaussian channels, recursive least-squares estimation and Kalman filtering by systolic arrays, Kemp echo digital filters, a periodic test-scheduling scheme for communication and queuing processes, and receivers for direct-sequence systems. Consideration is given to a distributed-parameter model for detecting cracks in rotors, active control of aeroelastic systems governed by functional differential equations, robust multivariable control of large space structures, finite-rank relatively bounded perturbations of semigroup generators, and sensitivity analysis of convex optimal-control problems. T.K.

A89-25873* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ROBUST MULTIVARIABLE CONTROL OF LARGE SPACE STRUCTURES
SURESH M. JOSHI (NASA, Langley Research Center, Hampton, VA) IN: International Conference on Advances in Communication and Control Systems, 1st, Washington, DC, June 18-20, 1987, Proceedings. New York, Optimization Software, Inc., 1988, p. 111-122. refs

The problem of designing attitude-control systems for large flexible space structures is considered. The difficulties which arise because of special dynamic characteristics are described, and methods for overcoming them using two type of controllers are presented. The first type of controller considered is a model-based compensator (MBC) and the second is the 'dissipative' controller which employs output feedback. Based on the analytical and numerical results obtained, the MBC can offer good performance under normal conditions, while the dissipative controller offers more robustness but perhaps reduced performance in situations involving larger uncertainties. Author

A89-26869
ACTIVE VIBRATION SUPPRESSION FOR THE MAST FLIGHT SYSTEM
FREDRIC M. HAM, SCOTT W. GREELEY, and BEN L. HENNIGES (Harris Corp., Government Aerospace Systems Div., Melbourne, FL) IEEE Control Systems Magazine (ISSN 0272-1708), vol. 9, Jan. 1989, p. 85-90.

Active vibration suppression of a large flexible space structure is addressed. The system (experimental test bed), performance requirements, and system simulations and models are described. The structure is a 60-m truss beam attached to the Shuttle Orbiter. A baseline control system is required to provide 5 percent structural damping for the first ten structural (flexible) modes of the truss beam. The control design approach used to achieve the damping is a decentralized velocity feedback type. Collocated actuator and sensor locations are given, with details of the model for the proof-mass actuating device, the linear dc motor. I.E.

A89-28499
LIAPUNOV STABILITY ANALYSIS FOR PDS CONTROL OF FLEXIBLE MULTI-LINK MANIPULATORS
HO GIL LEE, SUGURU ARIMOTO, and FUMIO MIYAZAKI (Osaka University, Toyonaka, Japan) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume

1. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 75-80. refs

For flexible multilink manipulators, a nonlinear lumped-parameter model including centrifugal and Coriolis forces is derived on the basis of Hamilton's principle and Galerkin's modal expansion method. A control scheme called PDS (proportional-derivative-strain) control is proposed, which is composed of a conventional PD control and feedback of strain detected at the root of each link. Stability conditions of the closed-loop system are obtained by using the moment equilibrium equation for the root of each link and the direct method of Liapunov. Effects of stabilization of this PDS control scheme are discussed for a linearized model. Experimental results are provided to illustrate the effectiveness of the proposed PDS control. I.E.

A89-28552#
SPACE STRUCTURE CONTROL USING MOVING BANK MULTIPLE MODEL ADAPTIVE ESTIMATION
ROBERT W. LASHLEE, JR. (U.S. Air Force Academy, Colorado Springs, CO) and PETER S. MAYBECK (USAF, Institute of Technology, Wright-Patterson AFB, OH) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 1. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 712-717. refs

The authors investigate the feasibility of applying moving-bank multiple-model adaptive estimation algorithms to flexible space-structure control. This form of estimation/control is an attempt to reduce the computational loading associated with the implementation of a full-scale multiple-model adaptive estimator/controller. It is shown that the moving-bank controller performs nearly identically to a benchmark controller and substantially better than a fixed-bank controller with a coarse discretization level that covers the entire range of parameter variation. I.E.

A89-28613
COMPUTATION OF THE STABILITY ROBUSTNESS OF LARGE STATE SPACE MODELS WITH REAL PERTURBATIONS
L. QIU and E. J. DAVISON (Toronto, University, Canada) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1380-1385. refs
(Contract NSERC-A-4396)

The authors address the computational problem encountered by a novel method of stability robustness analysis previously outlined, when it is applied to large systems. An iterative procedure is developed to compute the singular values and singular vectors of certain classes of large composite matrices; such a procedure can be used to solve problems which, because of dimensionality, cannot be solved by applying the QR transformation method. The procedure is then applied to the determination of stability robustness bounds of large-state-space systems with real perturbations. Various numerical examples, including a 46th-order spacecraft system, are given to illustrate the results obtained. I.E.

A89-28631
OPTIMAL REGULATION OF FLEXIBLE STRUCTURES GOVERNED BY HYBRID DYNAMICS
SAROJ K. BISWAS (Temple University, Philadelphia, PA) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1613-1618. refs

The author considers the problem of optimal control of flexible structures governed by a coupled system of ordinary differential equations and hyperbolic partial differential equations (hybrid dynamics). Necessary conditions are presented for determining the control torque and control forces for optimal regulation of the structure along with simultaneous suppression of its elastic vibrations. Illustrative numerical results for the control of a one-link flexible robot are presented. I.E.

A89-28632
BOUNDED INPUT FEEDBACK CONTROL OF LINEAR SYSTEMS WITH APPLICATION TO THE CONTROL OF A FLEXIBLE SYSTEM
H. KRISHNAN and M. VIDYASAGAR (Waterloo, University, Canada) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1619-1626. refs

The design of discrete-time H2 optimal controllers in the presence of constraints in the plant input is presented. The method is applied to the model of an experimental flex-arm, which has some nonminimum-phase zeros and all its poles on the unit circle. Experimental and simulation results on the performance of a fifth-order controller thus obtained are presented. The results suggest that this method of controller design ensures good performance of the closed-loop system. I.E.

A89-28633* Ohio State Univ., Columbus.
A FREQUENCY DOMAIN IDENTIFICATION SCHEME FOR FLEXIBLE STRUCTURE CONTROL
ANTHONY P. TZES and STEPHEN YURKOVICH (Ohio State University, Columbus) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1627-1632. refs
(Contract NAG1-720)

The authors present a novel method called time-varying transfer function estimation (TTFE) in which time-domain parameters are computed through identification in the frequency domain. The method is particularly well suited for flexible structure control problems. An example of a flexible manipulator system is presented for which a self-tuning control law with frequency shaping is derived and demonstrated. I.E.

A89-28637*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ON THE DESIGN OF THE DISSIPATIVE LQG-TYPE CONTROLLERS
R. LOZANO-LEAL and S. M. JOSHI (NASA, Langley Research Center, Hampton, VA) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1645, 1646. refs

The design of dissipative linear-quadratic-Gaussian-type compensators for positive real plants is considered. It is shown that if the noise covariance matrices (used as weighting matrices) satisfy certain conditions, the compensator has a strictly positive real transfer function matrix. The stability of the resulting closed-loop system is guaranteed regardless of modeling errors as long as the plant remains positive real. In view of this property, the controller is expected to be useful for vibration suppression in large, flexible space structures. I.E.

A89-28646
NONLINEAR DYNAMICS AND CONTROL ISSUES FOR FLEXIBLE SPACE PLATFORMS
H. G. KWATNY and W. H. BENNETT (Techno-Sciences, Inc., Greenbelt, MD) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1702-1707. Research supported by SDIO. refs
(Contract F49620-87-C-0103)

A description is given of the early results of an ongoing research program into the control of the nonlinear dynamics of large, flexible space structures. An approach to the modeling of generic space platforms is described, and the design of nonlinear feedback control systems via extract input-output linearization and decoupling as applied to this class of systems is also discussed. The role of nonlinear system zeros is highlighted. An example is given. I.E.

A89-28647* Illinois Univ., Urbana.
SLEW-INDUCED DEFORMATION SHAPING

T. A. W. DWYER, III (Illinois, University, Urbana) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1708-1713. Research supported by SDIO. refs
(Contract F49620-87-C-0103; NAG1-613)

Computed torques for pointing and tracking require compensation for slew-induced structural, forebody/aftbody, or optical train alignment deformations. Thus even if only line-of-sight variables are to be commanded, full state feedback is needed. The solution proposed is to decouple by feedforward of the line-of-sight slew dynamics into the deformation control loop. It is shown how arbitrarily few actuators are needed for such deformation shaping, at the cost of higher differentiability of the reference line-of-sight dynamics. The low-rate, single-axis case is developed in detail, and its extension to high rates and multiple axes by global feedback linearization is outlined. I.E.

A89-28652
NONLINEAR STABILIZATION OF TETHERED SATELLITES
D.-C. LIAW and E. H. ABED (Maryland, University, College Park) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 3. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1738-1745. refs
(Contract AF-AFOSR-87-0073; NSF ECS-86-57561; NSF CDR-85-00108)

A set of dynamic equations governing the dynamics of a tethered satellite system (TSS) and stabilizing tension control laws in feedback form are derived. The tether is assumed rigid and massless, and the equations of motion are derived using the system Lagrangian. It is observed that tools from stability analysis of critical nonlinear systems must be applied to stabilize the system. Tools related to the Hopf bifurcation theorem are used in the construction of the stabilizing control laws, which may be taken as purely linear. Simulations illustrate the nature of the conclusions, and show that nonlinear terms in the feedback can be used to improve the transient response significantly. I.E.

A89-30654#
SELECTIVE MODAL EXTRACTION FOR DYNAMIC ANALYSIS OF SPACE STRUCTURES
Y. C. YIU (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 21-31. Research supported by Lockheed Missiles and Space Co., Inc. refs
(AIAA PAPER 89-1163)

For problems with fixed spatial load distributions, the Load Dependent Ritz Vector basis provides a Ritz subspace for dynamic response evaluation. The eigensolution of this subspace provides the approximate modes shapes, hence the selected modes, to the original problem for modal superposition. In this paper, the mathematical basis of selective modal extraction is explained in terms of the conventional engineering analysis methods. The method is extended to structural systems with positive semidefinite stiffness matrices and hence suitable for dynamic analysis of space structures. Author

A89-30660#
EXPERIMENTAL ACTIVE VIBRATION DAMPING OF A PLANE TRUSS USING HYBRID ACTUATION
WILLIAM L. HALLAUER, JR. and STEVEN E. LAMBERSON (U.S. Air Force Academy, Colorado Springs, CO) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 80-90. Research sponsored by USAF. refs
(AIAA PAPER 89-1169)

The active vibration damping of a truss structure by the simultaneous use of air-jet thrusters (for low frequencies) and reaction-mass/force actuators (for high frequencies) is investigated analytically and experimentally. The characteristics of typical hardware components are reviewed and illustrated with drawings and photographs; the equations governing truss vibration and active damping are derived; and results for a beamlike plane truss are presented in graphs. Good damping is demonstrated using simple analog-computer controllers which integrate servo accelerometer signals to obtain velocity feedback. T.K.

A89-30704*# California Univ., Los Angeles.
CONTROL AUGMENTED STRUCTURAL SYNTHESIS WITH DYNAMIC STABILITY CONSTRAINTS
H. L. THOMAS and L. A. SCHMIT, JR. (California, University, Los Angeles) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 521-531. refs
(Contract NSG-1490)
(AIAA PAPER 89-1216)

Dynamic stability constraints are included in a computer program that simultaneously synthesizes a structure and its control system. Two measures of stability, the real part of the system complex eigenvalues and the damping ratio, are examined. The procedure for calculating the sensitivities of the two measures of stability to changes in the structure and its control system is explained. The sensitivities are used to formulate an approximate problem that is solved at each design iteration. The effects of structural damping and noncollated controllers on the synthesis process are discussed. Author

A89-30722*# Texas Univ., Austin.
MODEL REDUCTION AND CONTROL OF FLEXIBLE STRUCTURES USING KRYLOV SUBSPACES
ROY R. CRAIG, JR. (Texas, University, Austin) and TZU-JENG SU IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 691-700. refs
(Contract NAS9-17254)
(AIAA PAPER 89-1237)

Krylov vectors and the concept of parameter-matching are combined to develop a model reduction algorithm for a damped structural dynamics system. The reduced-order model obtained matches a certain number of low-frequency moments of the full-order system. The major application of the present method is to the control of flexible structures. It is shown that, in the control of flexible structures, there generally exist three types of control energy spillover, namely, the control spillover, the observation spillover, and dynamic spillover. The formulation based on Krylov subspaces can eliminate the control and the observation spillover, while leaving only the dynamic spillover to be considered. Two examples are used to illustrate the efficacy of the Krylov method. Author

A89-30769*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SELECTION OF ACTIVE MEMBER LOCATIONS IN ADAPTIVE STRUCTURES
G.-S. CHEN, R. BRUNO, and M. SALAMA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1127-1135. refs
(AIAA PAPER 89-1287)

The effective use of multiple passive and active members in adaptive structures necessitates that these members be optimally distributed throughout the structure. In truss structures, the problem falls into the class of combinatorial optimization for which the solution becomes exceedingly intractable as the problem size increases. This is overcome by using the simulated annealing algorithm to obtain near optimal locations for passive and/or active members. The maximization of the rate of energy dissipation over

a finite time period as the measure of optimality is adopted. The selection of optimal locations for both passive and active members is consistently treated through the use of the energy dissipation rate criterion within the simulated annealing algorithm. Numerical examples are used to illustrate the effectiveness of the methodology for large truss structures. Author

A89-30806*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ACTIVE-MEMBER CONTROL OF PRECISION STRUCTURES
J. L. FANSON, G. H. BLACKWOOD, and C. C. CHU (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1480-1494. refs
(AIAA PAPER 89-1329)

This paper presents the results of closed loop experiments that use piezoelectric active-members to control the flexible motion of a precision truss structure. These experiments are directed toward the development of high performance structural systems as part of the Control/Structure Interaction program at JPL. Order of magnitude reductions in dynamic response are achieved with relatively simple control techniques. The practical implementation of high stiffness, high bandwidth active-members in a precision structure highlights specific issues of importance relating to the modelling and implementation of active-member control. Author

A89-31029*# Honeywell, Inc., Glendale, AZ.
REACTION TORQUE MINIMIZATION TECHNIQUES FOR ARTICULATED PAYLOADS
KEVIN KRAL (Honeywell Sperry Space Systems, Glendale, AZ) and ROBERTO M. ALEMAN (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: ITC/USA/'88; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 17-20, 1988. Research Triangle Park, NC, Instrument Society of America, 1988, p. 419-429.

Articulated payloads on spacecraft, such as antenna telemetry systems and robotic elements, impart reaction torques back into the vehicle which can significantly affect the performance of other payloads. This paper discusses ways to minimize the reaction torques of articulated payloads through command-shaping algorithms and unique control implementations. The effects of reaction torques encountered on Landsat are presented and compared with simulated and measured data of prototype systems employing these improvements. Author

A89-31454#
NEW GENERALIZED STRUCTURAL FILTERING CONCEPT FOR ACTIVE VIBRATION CONTROL SYNTHESIS
BONG WIE and KUK-WHAN BYUN (Texas, University, Austin) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Mar.-Apr. 1989, p. 147-154. Previously cited in issue 22, p. 3639, Accession no. A87-50502. refs

A89-31455#
CONTROL OF FLEXIBLE STRUCTURES WITH SPILLOVER USING AN AUGMENTED OBSERVER
YOSSI CHAIT and CLARK J. RADCLIFFE (Michigan State University, East Lansing) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Mar.-Apr. 1989, p. 155-161. refs

Modern modal control methods for flexible structures have control and observation spillover that can degrade performance and reduce the stability margin of the closed-loop controlled structure. The sensor output is often filtered to reduce observation spillover; however, the filter introduces signal distortion and perturbs the closed-loop system eigenvalue locations. This perturbation can reduce the stability margin and jeopardize convergence of a deterministic observer. If the filter equations are not explicitly included in the observer design, then the separation principle between the controller and the observer states no longer holds when present in the unfiltered system. A new method is presented where the observer equations are augmented to include a first-order filter dynamics. The separation principle, controllability, and observability of the unfiltered system are invariant to the filter dynamics in this new method, resulting in no perturbation of controlled system eigenvalue locations. The filter cutoff frequency can be located even within the bandwidth of the system, thereby increasing the filter effectiveness in reducing observation spillover. Spillover-generated errors in closed-loop eigenvalues of these control methods are compared using a numerical example. Author

A89-31469*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
CONTROL-STRUCTURE INTERACTION IN PRECISION POINTING SERVO LOOPS
JOHN T. SPANOS (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Mar.-Apr. 1989, p. 256-263. refs

The control-structure interaction problem is addressed via stability analysis of a generic linear servo loop model. With the plant described by the rigid body mode and a single elastic mode, structural flexibility is categorized into one of three types: (1) appendage, (2) in-the-loop minimum phase, and (3) in-the-loop nonminimum phase. Closing the loop with proportional-derivative (PD) control action and introducing sensor roll-off dynamics in the feedback path, stability conditions are obtained. Trade studies are conducted with modal frequency, modal participation, modal damping, loop bandwidth, and sensor bandwidth treated as free parameters. Results indicate that appendage modes are most likely to produce instability if they are near the sensor rolloff, whereas in-the-loop modes are most dangerous near the loop bandwidth. The main goal of this paper is to provide a fundamental understanding of the control-structure interaction problem so that it may benefit the design of complex spacecraft and pointing system servo loops. In this framework, the JPL Pathfinder gimbal pointer is considered as an example. Author

N89-11262*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A COMPARATIVE OVERVIEW OF MODAL TESTING AND SYSTEM IDENTIFICATION FOR CONTROL OF STRUCTURES
J.-N. JUANG and R. S. PAPPA *In* Vibration Inst., The Shock and Vibration Digest, Volume 20, No. 6 p 4-15 Jun. 1988
Avail: NTIS HC A05/MF A01

A comparative overview is presented of the disciplines of modal testing used in structural engineering and system identification used in control theory. A list of representative references from both areas is given, and the basic methods are described briefly. Recent progress on the interaction of modal testing and control disciplines is discussed. It is concluded that combined efforts of researchers in both disciplines are required for unification of modal testing and system identification methods for control of flexible structures. Author

N89-11405# California Univ., Berkeley. Electronics Research Lab.
OPTIMIZATION-BASED DESIGN OF CONTROL SYSTEMS Final Report, 31 Jul. 1986 - 30 Jul. 1987
ELIJAH POLAK 13 Apr. 1988 4 p
(Contract AF-AFOSR-0247-86; AF PROJ. 2917)
(AD-A196593; AFOSR-88-0542TR) Avail: NTIS HC A02/MF A01
CSCL 12/6

A DEC MicroVax II GPX Color workstation has been acquired for experimentation with the DELIGHT.MIMO interactive software system in the solution of optimal, worst case design of multivariable control systems. A SUN workstation - based system has been expanded for experiments in distributed computing for the optimal, integrated design of flexible structures and their control systems. GRA

N89-11791*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
AN APPLICATION OF HIGH AUTHORITY/LOW AUTHORITY CONTROL AND POSITIVITY
S. M. SELTZER, D. IRWIN, D. TOLLISON (Control Dynamics Co., Huntsville, Ala.), and H. B. WAITES Aug. 1988 15 p
(NASA-TM-100338; NAS 1.15:100338) Avail: NTIS HC A03/MF A01 CSCL 22/2

Control Dynamics Company (CDy), in conjunction with NASA Marshall Space Flight Center (MSFC), has supported the U.S. Air Force Wright Aeronautical Laboratory (AFWAL) in conducting an investigation of the implementation of several DOD controls techniques. These techniques are to provide vibration suppression and precise attitude control for flexible space structures. AFWAL issued a contract to Control Dynamics to perform this work under the Active Control Technique Evaluation for Spacecraft (ACES) Program. The High Authority Control/Low Authority Control (HAC/LAC) and Positivity controls techniques, which were cultivated under the DARPA Active Control of Space Structures (ACOSS) Program, were applied to a structural model of the NASA/MSFC Ground Test Facility ACES configuration. The control systems design were accomplished and linear post-analyses of the closed-loop systems are provided. The control system designs take into account effects of sampling and delay in the control computer. Nonlinear simulation runs were used to verify the control system designs and implementations in the facility control computers. Finally, test results are given to verify operations of the control systems in the test facility. Author

N89-11921*# SatCon Technology Corp., Cambridge, MA.
AN ADVANCED ACTUATOR FOR HIGH-PERFORMANCE SLEWING Final Report
JAMES DOWNER, DAVID EISENHAURE, and RICHARD HOCKNEY Washington NASA Sep. 1988 163 p
(Contract NAS1-18322)
(NASA-CR-4179; NAS 1.26:4179; R05-87) Avail: NTIS HC A08/MF A01 CSCL 13/9

A conceptual design for an advanced momentum exchange actuator for application to spacecraft slewing is described. The particular concept is a magnetically-suspended, magnetically gimballed Control Moment Gyro (CMG). A scissored pair of these devices is sized to provide the torque and angular momentum capacity required to reorient a large spacecraft through large angle maneuvers. The concept described utilizes a composite material rotor to achieve the high momentum and energy densities to minimize system mass, an advanced superconducting magnetic suspension system to minimize system weight and power consumption. The magnetic suspension system is also capable of allowing for large angle gimballing of the rotor, thus eliminating the mass and reliability penalties attendant to conventional gimbals. Descriptions of the various subelement designs are included along with the necessary system sizing formulation and material.
Author

N89-12303# Lawrence Livermore National Lab., CA.
DECENTRALIZED ADAPTIVE CONTROL OF LARGE SCALE SYSTEMS, WITH APPLICATION TO ROBOTICS Ph.D. Thesis
DONALD T. GRAVEL, JR. Mar. 1988 117 p
(Contract W-7405-ENG-48)
(DE88-015409; UCRL-53866) Avail: NTIS HC A06/MF A01

Present day economic, technological, and environmental systems are large and complex. Gaining an understanding of large scale systems, that is, modeling their behavior and designing appropriate stabilizing controls, is a foremost challenge of modern system theory. One approach to large scale system modeling and control is decomposition of the large system into smaller, more manageable units. This is known as the decentralized approach. Decentralized control schemes have proven to be robust to a large range of uncertainties and nonlinearities in interconnections and subsystem dynamics. For the purpose of decentralized control, decompositions of large scale systems are typically formulated to isolate uncertainty about system behavior to the interaction between subsystems. Thereby the subsystems themselves are well modeled and decentralized controllers can be designed according to standard techniques. In this thesis, the theory of decentralized adaptive control for decentrally stabilizable systems has been developed. The new schemes depend upon local high gain feedback to stabilize local systems sufficiently to overcome interconnection disturbances. DOE

N89-13466*# Howard Univ., Washington, DC. Dept. of Mechanical Engineering.
STABILITY ANALYSIS OF LARGE SPACE STRUCTURE CONTROL SYSTEMS WITH DELAYED INPUT
A. S. S. R. REDDY and PETER M. BAINUM *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 123-132 Oct. 1988 Presented at the 6th VPI and SU/AIAA Symposium on Dynamics and Control of Large Structures
Avail: NTIS HC A17/MF A01 CSCL 22/2

Large space structural systems, due to their inherent flexibility and low mass to area ratio, are represented by large dimensional mathematical models. For implementation of the control laws for such systems a finite amount of time is required to evaluate the control signals; and this time delay may cause instability in the closed loop control system that was previously designed without taking the input delay into consideration. The stability analysis of a simple harmonic oscillator representing the equation of a single mode as a function of delay time is treated analytically and verified numerically. The effect of inherent damping on the delay is also analyzed. The control problem with delayed input is also formulated in the discrete time domain. Author

N89-13467*# Howard Univ., Washington, DC. Dept. of Mechanical Engineering.
THE DYNAMICS AND CONTROL OF THE IN-ORBIT SCOLE CONFIGURATION
PETER M. BAINUM, A. S. S. R. REDDY, CHEICK MODIBO DIARRA, and FEIYUE LI *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 145-180 Oct. 1988
(Contract NSG-1414)
Avail: NTIS HC A17/MF A01 CSCL 22/2

The study of the dynamics of the Spacecraft Control Laboratory Experiment (SCOLE) is extended to emphasize the synthesis of control laws for both the linearized system as well as the large amplitude slewing maneuvers required to rapidly reorient the antenna line of sight. For control of the system through small amplitude displacements from the nominal equilibrium position LQR techniques are used to develop the control laws. Pontryagin's maximum principle is applied to minimize the time required for the slewing of a general rigid spacecraft system. The minimum slewing time is calculated based on a quasi-linearization algorithm for the resulting two point boundary value problem. The effect of delay in the control input on the stability of a continuously acting controller (designed without considering the delay) is studied analytically for a second order plant. System instability can result even for delays which are only a small fraction of the natural period of motion.
Author

N89-13468*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INITIAL TEST RESULTS ON STATE ESTIMATION ON THE SCOLE MAST
D. SPARKS, JR. *In its* Proceedings of the 4th Annual SCOLE Workshop p 181-191 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

Modal state estimation tests are performed on the SCOLE mast for the fixed Shuttle platform case. Kalman filter state estimation results from a five mode computer model of the SCOLE mast, developed from a finite element analysis, are compared with those state estimates obtained from laboratory tests. Two comparison runs are presented, one an excitation of the first two bending modes, another, an excitation of the first torsional mode of the mast. Results from both runs show poor agreement in modal estimation between the computer model simulations and the laboratory test data. At present, the reason(s) for this poor

performance is unknown. Both the laboratory hardware and software and the computer model are being checked for possible sources of errors. Further computer simulations as well as laboratory testing will be performed. Author

N89-13469*# Control Research Corp., Lexington, MA.
SLEWING AND VIBRATION CONTROL OF THE SCOLE
JIGUAN GENE LIN *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 193-215 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

A discussion of Slewing and Vibration Control makes the following conclusions: (1) A 2-stage approach is feasible and promising for rapid slewing and precision pointing of SCOLE; (2) Not all bang-bang type of time-minimized slew maneuvers will excite large structural vibrations in SCOLE; and (3) Modal dashpots can be a concentrated high-power vibration control, as well as the usual diffuse (broadband, low-power (low-authority) control. The following recommendations are made: (1) Limit the magnitude of applied forces on reflector to either the 25-lb limit of vernier thrusters on the real Space Shuttle or the 150-lb level equivalent to the cold-gas jets of laboratory SCOLE; (2) to complete stage 2, add an integrated design of LQF/LTR (Linear-Quadratic-Gaussian/Loop-Transfer Recovery) and Modal Dashpots; and, (3) Validate the 2-stage approach using the SCOLE laboratory facility with a comprehensive sequence of integrated designs and experiments coupling nonlinear rigid-body motions with flexible-body dynamics. Author

N89-13473*# North Carolina Univ., Charlotte. Dept. of Electrical Engineering.
COMBINED PROBLEM OF SLEW MANEUVER CONTROL AND VIBRATION SUPPRESSION
Y. P. KAKAD *In* NASA, Langley Research Center, Proceedings of the 4th Annual SCOLE Workshop p 309-320 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

The combined problem of slew maneuver control and vibration suppression of NASA Spacecraft Control Laboratory Experiment (SCOLE) is considered. The coupling between the rigid body modes and flexible modes together with the effect of the control forces on the flexible antenna is discussed. The nonlinearities in the equations are studied in terms of slew maneuver angular velocities. Author

N89-13474*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ROBUST MODEL-BASED CONTROLLER SYNTHESIS FOR THE SCOLE CONFIGURATION
E. S. ARMSTRONG, S. M. JOSHI, and E. J. STEWART (George Washington Univ., Hampton, Va.) *In its* Proceedings of the 4th Annual SCOLE Workshop p 321-327 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

The design of a robust compensator is considered for the SCOLE configuration using a frequency-response shaping technique based on the LQG/LTR algorithm. Results indicate that a tenth-order compensator can be used to meet stability-performance-robustness conditions for a 26th-order SCOLE model without destabilizing spillover effects. Since the SCOLE configuration is representative of many proposed spaceflight experiments, the results and design techniques employed potentially should be applicable to a wide range of large space structure control problems. Author

N89-13475*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ANALYTIC REDUNDANCY MANAGEMENT FOR SCOLE
RAYMOND C. MONTGOMERY *In its* Proceedings of the 4th Annual SCOLE Workshop p 329-345 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

The objective of this work is to develop a practical sensor analytic redundancy management scheme for flexible spacecraft and to demonstrate it using the SCOLE experimental apparatus. The particular scheme to be used is taken from previous work on the Grid apparatus by Williams and Montgomery. Author

N89-13476*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A MATHEMATICAL PROBLEM AND A SPACECRAFT CONTROL LABORATORY EXPERIMENT (SCOLE) USED TO EVALUATE CONTROL LAWS FOR FLEXIBLE SPACECRAFT. NASA/IEEE DESIGN CHALLENGE
LAWRENCE W. TAYLOR, JR. and A. V. BALAKRISHNAN (California Univ., Los Angeles.) *In its* Proceedings of the 4th Annual SCOLE Workshop p 347-373 Oct. 1988
Avail: NTIS HC A17/MF A01 CSCL 22/2

The problen of controlling large, flexible space systems has been evaluated using computer simulation. In several cases, ground experiments have also been used to validate system performance under more realistic conditions. There remains a need, however, to test additional control laws for flexible spacecraft and to directly compare competing design techniques. A program is discussed which has been initiated to make direct comparisons of control laws for, first, a mathematical problem, then and experimental test article being assembled under the cognizance of the Spacecraft Control Branch at the NASA Langley Research Center with the advice and counsel of the IEEE Subcommittee on Large Space Structures. The physical apparatus will consist of a softly supported dynamic model of an antenna attached to the Shuttle by a flexible beam. The control objective will include the task of directing the line-of-sight of the Shuttle antenna configuration toward a fixed target, under conditions of noisy data, control authority and random disturbances. Author

N89-13764*# National Aeronautics and Space Administration. Pasadena Office, CA.
REMOTE OBJECT CONFIGURATION/ORIENTATION DETERMINATION Patent Application
LARRY L. SCHUMACHER, inventor (to NASA) (Jet Propulsion Lab., California Inst. of Tech., Pasadena.) 29 Aug. 1988 12 p (Contract NAS7-918)
(NASA-CASE-NPO-17436-1-CU; NAS 1.71:NPO-17436-1-CU; US-PATENT-APPL-SN-237035) Avail: NTIS HC A03/MF A01 CSCL 14/2

This invention relates to object detection and location systems and, more particularly, to a method for determining the configuration and location of an object with respect to an X, Y, X coordinate frame. In space applications in particular, there is a need to be able to passively determine the orientation of an object at a distance, for example, in the control of large, flexible space structures. At present, there is no available method or apparatus which will allow the operator to make such a determination. A similar problem and need exists in robotic application. It is the primary object of this invention to provide a system for remotely defining an object's configuration in a manner compatible with a computer's analytical capability. NASA

N89-15111*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RESULTS OF AN INTEGRATED STRUCTURE-CONTROL LAW DESIGN SENSITIVITY ANALYSIS
MICHAEL G. GILBERT Dec. 1988 21 p Presented at the 2nd NASA/Air Force Symposium on Recent Experiences in Multidisciplinary Analysis and Optimization, Hampton, VA, Sep. 1988
(NASA-TM-101517; NAS 1.15:101517) Avail: NTIS HC A03/MF A01 CSCL 01/3

Next generation air and space vehicle designs are driven by increased performance requirements, demanding a high level of design integration between traditionally separate design disciplines. Interdisciplinary analysis capabilities have been developed, for aeroservoelastic aircraft and large flexible spacecraft control for instance, but the requisite integrated design methods are only beginning to be developed. One integrated design method which has received attention is based on hierarchal problem decompositions, optimization, and design sensitivity analyses. This

paper highlights a design sensitivity analysis method for Linear Quadratic Cost, Gaussian (LQG) optimal control laws, which predicts change in the optimal control law due to changes in fixed problem parameters using analytical sensitivity equations. Numerical results of a design sensitivity analysis for a realistic aeroservoelastic aircraft example are presented. In this example, the sensitivity of the optimally controlled aircraft's response to various problem formulation and physical aircraft parameters is determined. These results are used to predict the aircraft's new optimally controlled response if the parameter was to have some other nominal value during the control law design process. The sensitivity results are validated by recomputing the optimal control law for discrete variations in parameters, computing the new actual aircraft response, and comparing with the predicted response. These results show an improvement in sensitivity accuracy for integrated design purposes over methods which do not include changess in the optimal control law. Use of the analytical LQG sensitivity expressions is also shown to be more efficient that finite difference methods for the computation of the equivalent sensitivity information. Author

N89-15156# General Analytic Corp., Athens, GA.
A NEW APPROACH TO THE ANALYSIS AND CONTROL OF LARGE SPACE STRUCTURES, PHASE 1 Final Report, 15 Oct. 1987 - 14 Mar. 1988
GEORGE ADOMIAN 12 Mar. 1988 129 p
(Contract F49620-87-C-0098)
(AD-A198143; GAC-881; AFOSR-88-0702TR) Avail: NTIS HC A07/MF A01 CSCL 22/5

The large structures contemplated would be constructed in space. Because of the limitations on launching massive payloads, it is clear that these structures will be made of lightweight material and will necessarily be flexible and easily excited into vibrations. Analytical problems will arise in designing large space structures in which physically realistic and accurate solutions will be critical. Such designs must consider weight, sizes, stiffness, thermal and mechanical distortions, stresses due to gravity and positioning thrusts. Some specific analytical problems will involve vibration, heating and cooling, multidimensional control, and structural problems arising from random support motion and random fluctuations of the system dynamic properties. GRA

N89-15158# Air Force Geophysics Lab., Hanscom AFB, MA.
A CHARGE CONTROL SYSTEM FOR SPACECRAFT PROTECTION
B. M. SHUMAN, H. A. COHEN, J. HYMAN, R. R. ROBSON, and W. S. WILLIAMSON (Hughes Research Labs., Malibu, CA.) 26 Sep. 1988 16 p
(Contract AF PROJ. 2823)
(AD-A199904; AFGL-TR-88-0246) Avail: NTIS HC A03/MF A01 CSCL 22/1

An autonomous system to detect both absolute and differential spacecraft charging aboard high altitude satellites, and to reduce those potentials before hazardous arcing levels are reached, is now being developed. Operation of the system is based on the empirical results of the Space Test Program SCATHA (p78-2) and NASA ATS-6 satellites, both of which successfully demonstrated the principle of safely reducing spacecraft charging levels by the emission of a low energy neutral plasma--effectively shorting the spacecraft and charged dielectric surfaces to the ambient space plasma. The Charge Control System will utilize a xenon-based plasma source capable of igniting within one second, and capable of emitting a quasi-neutral plasma containing more than 1 MA of ions. Satellite frame potential (relative to the ambient space plasma) will be determined by an electrostatic analyzer capable of detecting both ions and electrons in the energy range 50 eV to 20 keV. Automatic operation of the system will accomplished by microprocessor controller which will interpret the sensor data and activate the plasma source when predetermined threshold levels are exceeded. With a gas supply for more than 2000 hours of operation in space, the system may be expected to provide on-orbit spacecraft protection for up to 10 years. GRA

N89-15975*# Howard Univ., Washington, DC. Dept. of Mechanical Engineering.
THE DYNAMICS AND CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES, PART 11
PETER M. BAINUM, A. S. S. R REDDY, CHEICK M. DIARRA, and FEIYUE LI Aug. 1988 69 p
(Contract NSG-1414)
(NASA-CR-184770; NAS 1.26:184770) Avail: NTIS HC A04/MF A01 CSCL 22/2

A mathematical model is developed to predict the dynamics of the proposed Spacecraft Control Laboratory Experiment during the stationkeeping phase. The Shuttle and reflector are assumed to be rigid, while the mass connecting the Shuttle to the reflector is assumed to be flexible with elastic deformations small as compared with its length. It is seen that in the presence of gravity-gradient torques, the system assumes a new equilibrium position primarily due to the offset in the mass attachment point to the reflector from the reflector's mass center. Control is assumed to be provided through the Shuttle's three torquers and throught six actuators located by painrs at two points on the mass and at the reflector mass center. Numerical results confirm the robustness of an LQR derived control strategy during stationkeeping with maximum control efforts significantly below saturation levels. The linear regulator theory is also used to derive control laws for the linearized model of the rigidized SCOLE configuration where the mast flexibility is not included. It is seen that this same type of control strategy can be applied for the rapid single axis slewing of the SCOLE through amplitudes as large as 20 degrees. These results provide a definite trade-off between the slightly larger slewing times with the considerable reduction in over-all control effort as compared with the results of the two point boundary value problem application of Pontryagin's Maximum Principle.
Author

N89-16413*# Draper (Charles Stark) Lab., Inc., Cambridge, MA.
ON A USEFUL FUNCTIONAL REPRESENTATION OF CONTROL SYSTEM STRUCTURE
HARVEY L. MALCHOW Dec. 1988 17 p
(Contract NAS9-17560)
(NASA-CR-172109; NAS 1.26:172109; CSDL-P-2844) Avail: NTIS HC A03/MF A01 CSCL 09/2

An alternative structure for control systems is proposed. The structure is represented by a three-element block diagram and three functional definitions. It is argued that the three functional elements form a canonical set. The set includes the functions description, estimation and control. General overlay of the structure on parallel state and nested-state control systems is discussed. Breakdown of two real nested-state control systems into the proposed functional format is displayed. Application of the process to the mapping of complex control systems R and D efforts is explained with the Mars Rover Sample and Return mission as an example. A previous application of this basic functional structure to Space Station performance requirements organization is discussed. Author

N89-16901# Integrated Systems, Inc., Santa Clara, CA.
ADAPTIVE CONTROL TECHNIQUES FOR LARGE SPACE STRUCTURES Annual Technical Report, 1 Jun. 1986 - 31 May 1987
ROBERT L. KOSUT 23 Dec. 1987 91 p
(Contract F49620-85-C-0094)
(AD-A200208; ISI-110; AFOSR-88-0848TR) Avail: NTIS HC A05/MF A01 CSCL 22/2

This report summarizes the research performed on adaptive control techniques for Large Space Structures (LSS). The research effort concentrated on two areas: (1) on-line robust design from identified models - what is referred to here as adaptive calibration; and (2) an analysis of slow-adaptation for adaptive control of LSS. The report summarizes the results obtained in these areas and also includes Appendices which contain technical articles: (1) Adaptive Control of Large Space Structures; (2) Adaptive Control Via Finite Modeling and Robust Control; (3) On the use of the

Method of Averaging for the Stability analysis of Adaptive Linear Control Systems; and (4) Conditions for the Convergence and Divergence of Parameter Adaptive Linear Systems. GRA

N89-16902 Virginia Polytechnic Inst. and State Univ., Blacksburg.
SPILLOVER STABILIZATION IN THE CONTROL OF LARGE FLEXIBLE SPACE STRUCTURES Ph.D. Thesis
EVA A. CZAJKOWSKI 1988 285 p
Avail: Univ. Microfilms Order No. DA8817403

Active control of large flexible space structures is typically implemented to control only a few known elastic modes. Linear Quadratic Regulators (LQR) and Kalman-Bucy Filter (KBF) observers are usually designed to control the desired modes of vibration. Higher modes, referred to as residual modes, are generally ignored in the analysis and may be excited by the controller to cause a net destablizing effect on the system. This is referred to as spillover phenomenon. The stabilization of the neglected dynamics of the higher modes of vibration are considered. Modal controllers are designed with improved spillover stability properties. The proposed method calls for designing the observer so as to improve spillover stability with minimum loss in performance. Two formulations are pursued. The first is based on optimizing the noise statistics used in the design of the KBF. The second optimizies directly the gain matrix of the observer. Dissert. Abstr.

N89-17615 California Univ., Los Angeles.
SYMBOLIC GENERATION OF EQUATIONS OF MOTION FOR DYNAMICS/CONTROL SIMULATION OF LARGE FLEXIBLE MULTIBODY SPACE SYSTEMS Ph.D. Thesis
SHENG SAM LEE 1988 169 p
Avail: Univ. Microfilms Order No. DA8814809

The formulation of equations of motion has become crucial in the successful design of very large and flexible space vehicles. The derivation is presented of explicit equations of motion for multibody flexible space systems via symbolic manipulation. This methodology generates very efficient computational algorithms in a reasonable amount of time and cost. Kane's dynamical equations are used to formulate the equation of motion. The multibody system is idealized as a collection of interconnected bodies arranged in a topological tree configuration with the option that the bodies can form closed loops. The flexible characteristics of the bodies are described by means of assumed admissible spatial functions. Bodies of the system are interconnected by hinges possessing zero to six degrees of relative motion freedom with unrestricted large rigid body motion. Dissert. Abstr.

N89-18402*# National Aeronautics and Space Administration, Washington, DC.
CONTROLS AND GUIDANCE: SPACE
JOHN D. DIBATTISTA *In its* NASA Information Sciences and Human Factors Program p 105-125 Sep. 1988
Avail: NTIS HC A10/MF A01 CSCL 22/2

The Space Controls and Guidance Research and Technology Program is directed toward enabling the next generation of space transportation systems, large future spacecraft, and space systems such as the Space Station to have large communication antennas and high precision segmented reflector astrophysical telescopes. The new generation of transportation vehicles has demanding requirements to provide for an order of magnitude reduction in cost as well as an increase in capability. The future orbital facilities have demanding control requirements for pointing and stabilization, momentum management, build-up and growth accomodation, and disturbance management. To address these advanced requirements, the research and development program is designed to provide the generic technology base to support the implementation of advanced guidance, navigation, and control. The area of computational controls will be stressed in order to develop cost effective, high speed, high fidelity control system simulation and analysis and synthesis tools. The trust of this work will be to develop methods and software to enable analysis and real-time hardware-in-the-loop simulation of complex spacecraft for control design certification. To address future orbital facilities requirements, an advanced technology program is underway in system identification, distributed control, integrated controls/structures design methods, and advanced sensors and actuators. Because the behavior of larger, light weight per unit area deployable/assembled spacecraft is greatly influenced by the ground environment, the testing and verification activity is both ground- and space-based. Author

N89-19340# Virginia Univ., Charlottesville. Dept. of Mechanical and Aerospace Engineering.
SYSTEM IDENTIFICATION OF SUBOPTIMAL FEEDBACK CONTROL PARAMETERS BASED ON LIMITING-PERFORMANCE/MINIMUM-TIME CHARACTERISTICS
WALTER D. PILKEY *In its* Proceedings of the Fifth AFOSR Forum on Space Structures p 29-32 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

Most active controllers developed to control large structures are subject to constraints. For instance, control characteristics of proof-mass actuators are dominated by the nature of the constraints. To find the optimal or suboptimal control laws for such controllers can be a formidable task. Intuition of a designer plays an important role and the design method may vary dramatically in accordance with the constraints of the system. Therefore, one may wish to have a systematic methodology to solve the control problems subject to control force and state variable constraints. Limiting-performance/minimum-time (LP/MT) control calculates the optimal control force as a function of time for a known system with initial conditions, subject to certain constraints and external excitations while minimizing a given performance index. Although the LP/MT control gives optimal open loop control for the system, it is desirable to develop a closed loop control which has more practical value. Perhaps a system identification technique can be used to establish a suboptimal feedback control law based on the LP/MT control characteristics. Author

N89-19342# Massachusetts Inst. of Tech., Cambridge. Dept. of Aeronautics and Astronautics.
ACTIVE CONTROL OF ELASTIC WAVE MOTION IN STRUCTURAL NETWORKS
DAVID W. MILLER and ANDREAS H. VONFLOTOW *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 49-51 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

Recent work performed at the M.I.T. Space Systems Laboratory 1 has dealt with control design based on wave propagation models of flexible structures. Reflection and transmission properties of performance critical locations are actively altered in order to meet mission requirements regarding dynamic isolation, energy shunting, and vibration suppression. Using an input/output relation, the wave scattering characteristics of the location, or structural junction, can be actively altered in order to vary the path of power transmission or reduce power emanating from the junction. Such a technique has several advantages. Wave control approaches the problem as feedforward disturbance rejection of incoming waves. In some applications, this can eliminate resonant behavior by creating matched terminations. Local models are insensitive to all but local modelling errors. Since a wave model is a local description, a guarantee of control stability is not based upon knowledge of global structural behavior. Instead, stability is judged based on the frequency dependent power generation/dissipation properties of the active junction. Global control performance is dependent upon significance of the disturbance path containing the active junction. The control energy expended is of the order of the disturbance energy and only a few actuators and sensors are required to carry out most tasks. Author

N89-19343# Integrated Systems, Inc., Santa Clara, CA.
ADAPTIVE CONTROL OF LARGE SPACE STRUCTURES
ROBERT L. KOSUT *In* Virginia Univ., Proceedings of the Fifth

AFOSR Forum on Space Structures p 51-55 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

Some of the research issues involved in the design and analysis of adaptive control systems for large space structures (LSS) are described. The need for adaptive control arises from many envisioned future LSS missions which impose stringent performance demands on tracking accuracy and structural vibration attenuation. Both active feedback control and passive damping will be a practical necessity, and moreover, their design will require a model of the LSS system whose accuracy is compatible with the performance demands. Structural variations from many sources, such as deployment, material fatigue, and even random variations in materials and manufacturing tolerances, will significantly degrade closed-loop performance. Thus, the on-orbit dynamics of LSS will not be sufficiently like those obtained from either ground-testing or even from sophisticated computer generated modeling techniques, such as finite element modeling. Current structural modeling techniques are just not sufficiently accurate or able to account for all the possible sources of parameter variations. Therefore, under these conditions, it will be necessary to identify the LSS dynamics directly from on-orbit measurements, and simultaneously, tune or redesign the control. Hence, the control design cycle will be an adaptive process. Author

N89-19344# Harris Corp., Melbourne, FL. Government Aerospace Systems Div.
MAJORANT ANALYSIS OF PERFORMANCE DEGRADATION DUE TO UNCERTAINTY
DAVID C. HYLAND *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 57-64 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

The problem addressed here is the determination of bounds on the degradation of system performance due to uncertainties and/or unforeseen and imperfectly modelled subsystem interactions. Such bounding techniques represent a fundamental systems analysis tool that is indispensable for further elucidation of decentralized controller architectures and robust design. Author

N89-19346# Ohio State Univ., Columbus. Dept. of Electrical Engineering.
DECENTRALIZED/RELEGATED CONTROL FOR LARGE SPACE STRUCTURES
UMIT OZGUNER and STEVE YURKOVICH *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 73-75 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

The complexity of present and envisaged space structures dictates the inevitable need for emphasis on control and structure interaction. Moreover, in view of present methodologies, stringent control requirements such as precise pointing and slewing, vibration suppression, and shape control indicate that much work remains to be done in this important area. Recent results in the decentralized, relegated control of large space structures, with concentration on topics of decentralization, relegation, servomechanism design, and multiple mirror system examples are given. Author

N89-19347# Illinois Univ., Urbana. Coordinated Science Lab.
FROBENIUS-HANKEL NORM FRAMEWORK FOR DISTURBANCE REJECTION AND LOW ORDER DECENTRALIZED CONTROLLER DESIGN
J. MEDANIC and W. R. PERKINS *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 77-79 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

There is a desire to design low-order controllers for high order plants. Procedures to solve the low-order controller design problem can broadly be divided into two classes. Direct methods, in which the parameters defining a low order controller are computed by some optimization or other procedure, and indirect methods, in which a high order controller is found first, and then a procedure is used to simplify it. Examples of direct methods are the parametric linear-quadratic (LQ) design and the projective controls procedure developed by the authors. In the case of indirect methods, the linear-quadratic-Gaussian (LQG), the frequency weighted LQG, and the H (infinity)-norm minimization approaches provide the high order controller and, each in its own right, captures many relevant performance/robustness design goals. However, procedures for reducing high order controllers to low order controllers are less well developed. Author

N89-19355# Naval Postgraduate School, Monterey, CA.
EFFECTS OF REDUCED ORDER MODELING ON THE CONTROL OF A LARGE SPACE STRUCTURE M.S. Thesis
WILLIAM J. PRESTON Sep. 1988 81 p
(AD-A201674) Avail: NTIS HC A05/MF A01 CSCL 22/2

The motion of a large space structure, such as a space station, is described by a large number of coupled, second order differential equations. To effectively control this structure, a mathematical model is required. Both the mathematical model developed directly from the physics of the structure, and the simplified model developed with modal analysis are of extremely high dimension. A reduced order model is therefore required in order to design a control system for the structure. A straightforward approach to the control problem is taken by using linear quadratic optimal control techniques to determine the reduced order control solution for the truncated modal model. The effects of reduced order modeling on the control of the space station will be evaluated by observing the response of the closed loop system to several disturbances. GRA

N89-19356 Virginia Polytechnic Inst. and State Univ., Blacksburg.
NONLINEAR OPTIMAL CONTROL AND NEAR-OPTIMAL GUIDANCE STRATEGIES IN SPACECRAFT GENERAL ATTITUDE MANEUVERS Ph.D. Thesis
YIING-YUH LIN 1988 94 p
Avail: Univ. Microfilms Order No. DA8825331

Solving the optimal open-loop control problems for spacecraft large-angle attitude maneuvers generally requires the use of numerical techniques whose reliability is strongly case dependent. The primary goal of this dissertation is to increase the solution reliability of the associated nonlinear two-point boundary-value problems as derived from Pontryagin's Principle. Major emphasis is placed upon the formulation of the best possible starting or nominal solution. Constraint relationships among the state and costate variables are utilized. A hybrid approach which begins with the direct gradient method and ends with the indirect method of particular solutions is proposed. Test case results which indicate improved reliability are presented. The nonlinear optimal control law derived from iterative procedures cannot adjust itself in accordance with state deviations measured during the control period. A real-time near-optimal guidance scheme which takes the perturbed states to the desired manifold by tracking a given optimal trajectory is also presented. Numerical simulations are presented which show that highly accurate tracking results can be achieved. Dissert. Abstr.

N89-19596# Texas A&M Univ., College Station. Dept. of Aerospace Engineering.
CONTROL OF FLEXIBLE STRUCTURES: MODEL ERRORS, ROBUSTNESS MEASURES, AND OPTIMIZATION OF FEEDBACK CONTROLLERS Final Report, 1 Jun. 1986 - 31 Aug. 1988
JOHN L. JUNKINS and S. R. VADALI 31 Oct. 1988 300 p
(Contract F49620-86-K-0014)
(AD-A202234; AFOSR-88-1252TR) Avail: NTIS HC A13/MF A01 CSCL 22/2

This report summarizes new methods for flexible structures' dynamic analysis, system identification, and maneuver controls. New control design methods are introduced for considering several competing performance measures simultaneously. A new attitude control method using single gimbal control moment gyros is introduced. New results and insights on singularity avoidance are

presented. A method is given for simultaneous optimization of structural design parameters and feedback controller. GRA

N89-19855*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
INTELLIGENT TUTORING IN THE SPACECRAFT COMMAND/CONTROL ENVIRONMENT
WALTER F. TRUSZKOWSKI *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 279-286 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 09/2

The spacecraft command/control environment is becoming increasingly complex. As we enter the era of Space Station and the era of more highly automated systems, it is evident that the critical roles played by operations personnel in supervising the many required control center system components is becoming more cognitively demanding. In addition, the changing and emerging roles in the operations picture have far-reaching effects on the achievement of mission objectives. Thus highly trained and competent operations personnel are mandatory for success. Keeping pace with these developments has been computer-aided instruction utilizing various artificial intelligence technologies. The impacts of this growing capability on the stringent requirements for efficient and effective control center operations personnel is an area of much concentrated study. Some of the research and development of automated tutoring systems for the spacecraft command/control environment is addressed. Author

07

POWER

Includes descriptions of analyses, systems, and trade studies of electric power generation, storage, conditioning and distribution.

A89-11122#
HIGH-VOLTAGE SOLAR CELL MODULES IN SIMULATED LOW-EARTH-ORBIT PLASMA
HEINZ THIEMANN (Physikalisch Technische Studien GmbH, Freiburg im Breisgau, Federal Republic of Germany) and KLAUS-PETER BOGUS (ESA, Technical Directorate, Noordwijk, Netherlands) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 25, July-Aug. 1988, p. 278-285. refs

The behavior of solar cell modules at high voltages in a surrounding simulated LEO plasma has been characterized over an applied voltage range from -700 to +500 V. Measurements were obtained in a large chamber under high vacuum using argon ions from a Kaufman source to generate a high-density plasma of up to 10 to the 6th/cu cm. The results suggest that secondary electrons contribute to the anomalous current increase noted at positive module voltages above 300 V. The surface potential on the coverglasses of the solar cells was shown to increase to high values only in the vicinity of the interconnectors. R.R.

A89-11406* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
THE TECHNOLOGY ISSUES AND THE PROSPECTS FOR THE USE OF LITHIUM BATTERIES IN SPACE
GERALD HALPERT and S. SUBBARAO (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Symposium on Primary and Secondary Ambient Temperature Lithium Batteries, Honolulu, HI, Oct. 18-23, 1987, Proceedings. Pennington, NJ, Electrochemical Society, Inc., 1988, p. 129-145.
(Contract NAS7-918)

Lithium Primary and Secondary Cells are being considered for applications in space to enhance energy storage capability. In this paper the authors describe the past, present and future application and program objectives as well as the technology issues that must be addressed. Author

A89-12128#
THE 1986 IAEA CONVENTIONS ON NUCLEAR ACCIDENTS AND THE CONSIDERATION OF THE USE OF NUCLEAR POWER SOURCES IN OUTER SPACE IN THE LEGAL SUB-COMMITTEE OF COPUOS
ANDREI D. TEREKHOV (UN, Office of Legal Affaires, New York) IN: Colloquium on the Law of Outer Space, 30th, Brighton, England, Oct. 10-17, 1987, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 403-410. refs

The accident-notification and accident-assistance conventions adopted by the International Atomic Energy Authority (IAEA) after the Chernobyl accident in 1986 are examined, with a focus on their legal implications for space nuclear power systems. The IAEA texts are confronted with a draft version of similar principles for space systems, presented to and adopted by the COPUOS Legal Subcommittee in March-April 1986. It is pointed out that the IAEA conventions make specific reference to space systems and include them in their provisions, so that adoption of separate space nuclear treaties or regulations could create ambiguities unless care is taken to make the space legislation fully consistent and compatible with the IAEA provisions. This is considered especially important because, like similar draft principles on remote sensing and satellite direct broadcasting, the COPUOS rules will probably not achieve legally binding status. T.K.

A89-14967
PHASE I SPACE STATION POWER SYSTEM DEVELOPMENT
ROBERT O. PRICE Aerospace Engineering (ISSN 0736-2536), vol. 8, Oct. 1988, p. 19-23.

The development of the electric power system (EPS) for the Space Station is discussed. The EPS requirements related to station size, operational lifetime, operational autonomy, and technology evolution are considered. It is suggested that environmental control and life support will require 55 kWe of power. The possible use of solar photovoltaic, solar thermal dynamic, or a hybrid combination of the two are examined. R.B.

A89-15176
1988 IECEC; PROCEEDINGS OF THE TWENTY-THIRD INTERSOCIETY ENERGY CONVERSION ENGINEERING CONFERENCE, DENVER, CO, JULY 31-AUG. 5, 1988. VOLUMES 1, 2, 3, & 4
D. YOGI GOSWAMI, ED. Conference sponsored by ASME, IEEE, AIAA, et al. New York, American Society of Mechanical Engineers, 1988, p. Vol. 1, 635 p.; vol. 2, 567 p.; vol. 3, 815 p.; vol. 4, 621 p. For individual items see A89-15177 to A89-15420.

The present conference discusses topics in Stirling engine development, heat pump applications of Stirling powerplants, Stirling cycle modeling, Stirling engine component modeling and testing, design procedures for Stirling cycle machines, Stirling cycle test results, applications of the Stirling cycle as an engine, thermochemical heat engines, heat engine technology development, thermoelectric power, thermal rejection systems, advanced cycles and systems, advanced light water nuclear reactors, liquid metal reactors, modular high temperature gas-cooled reactors, advanced fission reactors, thermionic power, aerospace and terrestrial energy storage, thermal energy storage, fuel cell development and applications, space and terrestrial battery energy storage, lithium batteries, Ni-Cd and Ag-Zn batteries, Ni-H spacecraft batteries, and space and terrestrial applications of superconductivity. Also discussed are space and terrestrial applications of photovoltaics, isotopic fuel power sources, space nuclear power systems, space power automation, Space Station solar dynamic power generation/storage, Space Station photovoltaics, Space Station automation, pulse/MW space power, space MHD applications, wind energy, energy conservation, solar heating/cooling, solar energy conversion, electrical propulsion, alternative fuels, municipal solid waste energy, and MHD commercialization. O.C.

A89-15199
LIQUID METAL THERMAL ELECTRIC CONVERTER THEORETICAL AND EXPERIMENTAL STUDIES

JAMES P. MORENO, JOSEPH P. ABBIN, CHARLES E. ANDRAKA, and LAURENCE L. LUKENS (Sandia National Laboratories, Albuquerque, NM) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 1. New York, American Society of Mechanical Engineers, 1988, p. 235-240. Previously announced in STAR as N88-25974. refs

The Liquid Metal Thermal Electric Converter (LMTEC) is a thermodynamic heat engine with no moving parts that has the potential for high efficiency and low operating and maintenance costs in a number of terrestrial and space applications. At Sandia National Laboratories, the LMTEC has been studied theoretically and experimentally as a candidate for solar dish electric systems. The primary goals have been to improve and adapt the existing technology to solar requirements. As part of this effort, a 25-kWe solarized LMTEC conceptual design was produced and a bench test module (BTM) was constructed and tested. The BTM incorporated a number of new design innovations that were conceived especially for a solarized LMTEC. The maximum electrical power extracted from the BTM was a small fraction of the level expected. Using a detailed computer model for BTM performance, the major results were shown to be consistent with high electrode flow resistance. The same conclusion was reached using a new experimental electrode evaluation technique. Thus the performance was limited by the particular electrode that was used and not in any fundamental way be the design innovations. Author

A89-15211
ROTATING FILM RADIATOR FOR HEAT REJECTION IN SPACE

JEAN F. LOUIS (MIT, Cambridge, MA) and SEUNG JIN SONG IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 1. New York, American Society of Mechanical Engineers, 1988, p. 385-390. Research supported by Sundstrand Corp. refs

After a review of advanced radiator concepts, a rotating film radiator concept is analyzed to reduce the radiator mass in solar dynamic power systems. The concept envisions a rotating disk with a thin film of radiator liquid flowing radially outward while radiating directly to space. The radiator concept only utilizes currently existing technologies and overcomes containment problems faced by another concept, the rotating bubble membrane radiator, which is also analyzed. A preliminary design suggests that the rotating film radiator can achieve a specific mass of 5.5 kg/kWt or 3.5 kg/m-squared. Author

A89-15212
A CONDENSER-BOILER FOR A BINARY RANKINE CYCLE SPACE POWER SYSTEM

RANDY M. COTTON (U.S. Space Command, Peterson AFB, CO) and JEAN F. LOUIS (MIT, Cambridge, MA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 1. New York, American Society of Mechanical Engineers, 1988, p. 399-404. Research supported by Sundstrand Corp. refs

A theoretical design is described for the condenser/boiler of a space-based dynamic power system. The base system is a binary Rankine cycle with mercury and toluene as the working fluids. The system output is 75 KWe (kilowatt electric) with a combined efficiency of 41.1 percent. The toluene flow is supercritical to avoid two-phase flow difficulties, and the mercury flow is designed to match with the highest heat transfer coefficients achieved during the SNAP-3 experiments. Whereas previous estimates indicate an achievable specific mass on the order of 0.11 kg/KWth, the present design has a specific mass of 0.016 kg/KWth, including toluene ducting and protective shell. The resulting design utilizes pure molybdenum for all heat transfer surfaces, it transfers 137.46 kilowatts of thermal power, it can oeprate at varying mass flow rates, and it has efficiencies in heat transfer of 0.96. The effect of varying mass rates is also investigated to determine the part load operation. Author

A89-15213
THE HIGH TEMPERATURE GAS-COOLED REACTOR - A VERSATILE NUCLEAR HEAT SOURCE FOR SPACE, TERRESTRIAL, MOBILE, SUBTERRANEAN AND UNDERSEA POWER APPLICATIONS

COLIN F. MCDONALD (General Atomics Corp., San Diego, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 1. New York, American Society of Mechanical Engineers, 1988, p. 543-548. refs

The key element in the deployment, performance, and safety of the High-Temperature Gas-Cooled Reactor (HTGR) is the utilization of proven high integrity microsphere fuel particles with their ceramic coatings which form a containment system which places primary emphasis on retention of fission products in the fuel. The basic particles can be embodied in a variety of different fuel element types, core sizes and geometries, and with a reactor outlet gas temperature capability up to 1000 C, the gas-cooled reactor offers opportunities, unmatched by any other reactor type, for a wide spectrum of applications including electrical power generation, process heat supply, and propulsion. This paper highlights the versatility of the gas-cooled reactor for projected applications which will become paramount in the 21st century. Author

A89-15220
ADVANCED THERMIONIC NUCLEAR ELECTRIC PROPULSION FOR LEO TO GEO TRANSFER IN 14 DAYS

ELLIOT B. KENNEL and MARK S. PERRY (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 1. New York, American Society of Mechanical Engineers, 1988, p. 597-600. refs

Advanced thermionic nuclear power supplies can be designed for extraordinary performance for short lifetime applications. This could enable electric propulsion for use on orbital tugs with a transfer time of two weeks or less, rather than 150 to 200 days as in the traditional approach. Payloads in excess of 17,000 kg are possible in geosynchronous orbit, far in excess of the capability of the existing Space Shuttle Upper Stage. Author

A89-15221
CHARACTERIZATION OF COMPLIANT THERMAL CONDUCTIVE TUNGSTEN MATERIAL FOR THERMIONIC ELEMENT APPLICATION

V. TRUJILLO, M. MERRIGAN, and W. RANKEN (Los Alamos National Laboratory, NM) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 1. New York, American Society of Mechanical Engineers, 1988, p. 601-605.

The two compliant, thermally conductive, tungsten-based materials that have been developed for use by the Thermionic Fuel Element Verification program are to be inserted between UO2 fuel cylinders and the copper cladding thst surrounds them in order to absorb swelling and reduce tungsten emitter element stress. Test procedures and test results are presented, with attention to the anticipated effects on thermionic element lifetime; lifetimes of the order of 7 years appear to be achievable by means of the buffer materials. O.C.

A89-15230
ELECTRICAL MACHINE FOR FLYWHEEL SYSTEM EMAFER

R. B. VAN DER MEER (CCM, Nuenen; Eindhoven, Technische Hogeschool, Netherlands) and J. S. RIETEMA (CCM, Nuenen, Netherlands) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 2. New York, American Society of Mechanical Engineers, 1988, p. 47-52. refs

The choice of the electrical machine for the EMAFER (electromechanical accumulator for energy reuse) flywheel system is considered. A synchronous machine with permanent-magnet

excitation and power capacity of 300 kW over its entire range of operation is projected. The first test runs have been done with a prototype converter capable of delivering up to 30 kW at 600 Hz. B.J.

A89-15245* Sanders Associates, Inc., Nashua, NH.
AN EXPERIMENTAL ANALYSIS OF A DOPED LITHIUM FLUORIDE DIRECT ABSORPTION SOLAR RECEIVER
JAMES KESSELI, TOM POLLAK (Sanders Associates, Inc., Nashua, NH), and DOVIE LACY (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 2. New York, American Society of Mechanical Engineers, 1988, p. 179-185.

An experimental analysis of two key elements of a direct absorption solar receiver for use with Brayton solar dynamic systems was conducted. Experimental data are presented on LiF crystals doped with dysprosium, samarium, and cobalt fluorides. In addition, a simulation of the cavity/window environment was performed and a posttest inspection was conducted to evaluate chemical reactivity, transmissivity, and condensation rate. B.J.

A89-15256
'HYTEC': HYDROGEN THERMO-ELECTROCHEMICAL CONVERTER - AN INNOVATIVE CONCEPT FOR SPACE POWER APPLICATIONS
P. ROY, J. S. ARMIJO, and E. E. GERRELS (General Electric Co., Astro-Space Div., San Jose, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 2. New York, American Society of Mechanical Engineers, 1988, p. 287-280.

This paper describes the principles and status of development of a new and innovative high efficiency, thermally regenerative fuel cell conversion system recently conceived at GE. When proven through experiment and theoretical analysis, the concept, based on high temperature hydrogen transport, has potential to make high efficiency direct energy conversion a practical reality for spacecraft applications. Author

A89-15257* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
HYBRID REGENERATIVE FUEL CELL SYSTEMS FOR SPACE APPLICATIONS
DAVID R. SAUCIER (NASA, Johnson Space Center, Houston, TX) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 2. New York, American Society of Mechanical Engineers, 1988, p. 291-295.

This paper describes a hybrid regenerative fuel cell (RFC) system for space application, which is made up of an alkaline fuel cell (Space Shuttle fuel cell) and an acid electrolysis unit (solid polymer electrolyte). In the RFC, gas produced from the acid electrolysis unit and water produced by the alkaline fuel cell are repeatedly reacted in the other unit. The results of RFC's tests indicate that the system is feasible in terms of fluid/unit compatibility. In addition, the fuel cell thermal-control system proved capable of controlling fuel cell temperatures throughout long open-circuit periods. Diagrams of the RFC and its subsystems are included. I.S.

A89-15275
NEW APPLICATION OF SILVER-ZINC BATTERIES FOR ORBITING SPACECRAFT
A. P. KARPINSKI (Whittaker Technical Products, Inc., Pawcatuck, CT) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 2. New York, American Society of Mechanical Engineers, 1988, p. 431-437.

Three groups of 250 ampere-hour silver-zinc cells were studied in support of various NASA applications which include the Space Station initiative. It is shown that the silver zinc couple is capable of nine consecutive monthly charged stand periods, with 70 percent depth of discharge (DOD) cycling at the end of each period. It is also capable of up to 3100 continuous low DOD simulated LEO cycles and of providing high energy densities. K.K.

A89-15276
DYNAMIC PERFORMANCE BATTERY MODEL
THOMAS C. LEISGANG, SHEILA J. JOHNSON, and DOUGLAS P. HAFEN (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 2. New York, American Society of Mechanical Engineers, 1988, p. 439-441.

A battery modeling algorithm has been developed that simulates battery voltage and coulombic efficiency characteristics in a dynamic cycling environment. The model is used in a DC energy balance calculation for spacecraft electrical power system applications. The voltage prediction model is based on laboratory cycling test data as a function of battery temperature, current, state-of-charge, and cycle life. The coulombic efficiency model is a function of temperature, current, and state-of-charge. The battery modeling algorithm simulates battery operation in four modes, which include charge, discharge, trickle charge, and trickle discharge. Author

A89-15282
CAPACITY AND PRESSURE VARIATION OF INTELSAT VI NICKEL-HYDROGEN CELLS WITH STORAGE AND CYCLING
H. VAIDYANATHAN and M. W. EARL (COMSAT Laboratories, Clarksburg, MD) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 2. New York, American Society of Mechanical Engineers, 1988, p. 471-475. INTELSAT-sponsored research.

The paper evaluates the ability of nickel-hydrogen cells to maintain their capacity under different storage conditions, such as trickle discharge, periodic recharge, and discharged open-circuit-stand at room temperature and 0 C. Intelsat VI flight cells of the Air Force/Hughes recirculating design with two layers of Zircar as separator are used. It is found that the trickle-charge and periodic-recharge storage modes maintained capacity, while at 0 C storage, only the positive-precharge cell capacity was maintained. K.K.

A89-15284
NICKEL-HYDROGEN CELL LIFE TESTING
DWAINE K. COATES and RUSSELL M. BARNETT (Eagle-Picher Industries, Inc., Joplin, MO) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 2. New York, American Society of Mechanical Engineers, 1988, p. 483-488.

Ninety nickel-hydrogen cells are being life tested in eight independent groups. The nominal capacity of the cells range from thirty to eighty ampere-hours. The tests have accumulated a range of 1500 to 32,000 cycles. Three different cycle regimes are being used and depths-of-discharge range from 15 to 50 percent. Several cells have been disassembled throughout testing. An investigation into failure mechanisms is being conducted. Testing is planned to continue indefinitely. Author

A89-15285
THE NI-H2 BATTERY SYSTEM - A SPACE FLIGHT APPLICATION SUMMARY
LEE MILLER (Eagle-Picher Industries, Inc., Joplin, MO) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 2. New York, American Society of Mechanical Engineers, 1988, p. 489-492.

This paper presents the summary of space flight applications of Ni-H2 battery system in 38 programs which have flown, are flying. or will be launched. Data for these programs are presented in a tabular format, together with pertinent information, such as

the name of the prime contractor, the name of the mission, the duration, the battery capacity and size, and the launch date. I.S.

A89-15287* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE APPLICATION OF HIGH TEMPERATURE SUPERCONDUCTORS TO SPACE ELECTRICAL POWER DISTRIBUTION COMPONENTS
PAUL R. ARON and IRA T. MYERS (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 2. New York, American Society of Mechanical Engineers, 1988, p. 501-503. Previously announced in STAR as N88-22939. refs

Some important space based electrical power distribution systems and components are examined to determine what might be achieved with the introduction of high temperature superconductors (HTS). Components that are compared in a before-and-after fashion include transformers, transmission lines, and capacitors. It is concluded that HTS has its greatest effect on the weight associated with transmission lines, where the weight penalty could be reduced by as much as 130 kg/kW/km of cable. Transformers, because 28 percent of their mass is in the conductor, are reduced in weight by the same factor. Capacitors are helped the least with only negligible savings possible. Finally, because HTS can relax the requirement to use alternating current in order to reduce conductor mass, it will be possible to generate significant savings by eliminating most transformers and capacitors. Author

A89-15288* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
HIGH TEMPERATURE SUPERCONDUCTING MAGNETIC ENERGY STORAGE FOR FUTURE NASA MISSIONS
KARL A. FAYMON (NASA, Lewis Research Center, Cleveland, OH) and STANLEY J. RUDNICK (Argonne National Laboratory, IL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 2. New York, American Society of Mechanical Engineers, 1988, p. 511-514. refs

Several NASA sponsored studies based on 'conventional' liquid helium temperature level superconductivity technology have concluded that superconducting magnetic energy storage has considerable potential for space applications. The advent of high temperature superconductivity (HTSC) may provide additional benefits over conventional superconductivity technology, making magnetic energy storage even more attractive. The proposed NASA space station is a possible candidate for the application of HTSC energy storage. Alternative energy storage technologies for this and other low Earth orbit missions are compared. Author

A89-15292* National Aeronautics and Space Administration, Washington, DC.
SPACE POWER TECHNOLOGY TO MEET CIVIL SPACE REQUIREMENTS
EARL VANLANDINGHAM (NASA, Propulsion, Power, and Energy Div., Washington, DC) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 9-16.

The current status of NASA R&D programs for space power systems is reviewed and illustrated with drawings and diagrams. Topics addressed include photovoltaic systems, energy-storage technology, solar-dynamic systems, the SP-100 Advanced Technology Program, Stirling engine technology, and thermal management. Consideration is given to power management and distribution, power-system autonomy, high-Tc superconductor technology, space power materials, and environmental interactions. T.K.

A89-15293
PROGRESS TOWARDS THE DEVELOPMENT OF POWER GENERATION AND POWER CONDITIONING TECHNOLOGIES FOR SDIO
R. VERGA and D. BUDEN (SDIO, Washington, DC) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 17-22.

The current status of power-systems R&D for the U.S. Strategic Defense Initiative is surveyed and illustrated with diagrams and graphs. Topics discussed include the power requirements of proposed weapon and sensor systems, baseload power-system development (mainly solar), power-system environments, space burst power systems, ground-based power systems, pulse-power and power-conditioning subsystems, and power transmission. T.K.

A89-15295* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SPACE STATION POWER SYSTEM REQUIREMENTS
JOHN W. DUNNING, JR. (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 29-36. Previously announced in STAR as N88-21245.

Presented is an overview of the requirements on which the Space Station Electric Power System is based as well as a summary of the design itself. The current design, which is based on silicon photovoltaic arrays, NiH2 batteries, and 20 kHz distribution technology, meets all of the requirements. Author

A89-15296
EXPERIMENTAL EVALUATION OF A SOLAR THERMOPHOTOVOLTAIC ENERGY CONVERSION MODULE
W. E. HORNE (Boeing Electronics Co., Seattle, WA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 37-42.

A solar thermophotovoltaic concept has been modeled, fabricated, and tested. The module consists of a hexagonal parabolic primary reflector in a Cassegrain concentrator configuration. Heat pipes extending radially from the base distribute heat to the primary collector which doubles as thermal radiator as well as solar concentrator. Predictions indicate operational efficiencies in excess of 30 percent are practical for the system. Author

A89-15297
SOLAR CELL REVERSE BIASING AND POWER SYSTEM DESIGN
CRAIG BECKER-IRVIN (Aerospace Corp., Electronics and Optics Div., El Segundo, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 43-47.

This paper reviews the solar-cell reverse-biasing phenomenon and explores the parameters that affect reverse biasing of shadowed solar cells. Power-system design features which can minimize the detrimental effects of shadowing are also examined. Author

A89-15298* Rockwell International Corp., Canoga Park, CA.
AN INTEGRATED AND MODULAR DIGITAL MODELING APPROACH FOR THE SPACE STATION ELECTRICAL POWER SYSTEM DEVELOPMENT
FRANK J. GOMBOS (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) and NARAYAN DRAVID (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 49-55. Previously announced in STAR as N88-22935. refs

An electrical power system for the Space Station was designed, developed and built. This system provides for electrical power

generation, conditioning, storage, and distribution. The initial configuration uses photovoltaic power generation. The power system control is based on a hierarchical architecture to support the requirements of automation. In the preliminary design and technology development phase of the program, various modeling techniques and software tools were evaluated for the purpose of meeting the Space Station power system modeling requirements. Rocketdyne and LeRC jointly selected the EASY5 simulation software, developed by Boeing Computer Services, as a system level modeling tool. The application of the selected analytical modeling approach to represent the entire power system is described. Typical results of model predictions are also summarized. The equipment modeled includes solar arrays, dc to ac converters, resonant inverters, battery storage system, alternator, transmission line, switch gear, and system level microprocessor controls. During the advanced development phase of this program, several models were developed using this approach. Author

A89-15299* Martin Marietta Aerospace, Denver, CO.
POWER CONDITIONING FOR LARGE DC MOTORS FOR SPACE FLIGHT APPLICATIONS
MARTIN S. VEATCH, PAUL M. ANDERSON, DOUGLAS J. EASON, and DAVID M. LANDIS (Martin Marietta Corp., Denver, CO) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 57-62.
(Contract NAS8-36000)

The design and performance of a prototype power-conditioning system for use with large brushless dc motors on NASA space missions are discussed in detail and illustrated with extensive diagrams, drawings, and graphs. The 5-kW 8-phase parallel module evaluated here would be suitable for use in the Space Shuttle Orbiter cargo bay. A current-balancing magnetic assembly with low distributed inductance permits high-speed current switching from a low-voltage bus as well as current balancing between parallel MOSFETs. T.K.

A89-15300
LATENT THERMAL STORAGE FOR SPACE SOLAR DYNAMIC POWER SYSTEM
KOTARO TANAKA, YOSHIYUKI ABE, YOSHIO TAKAHASHI, MASAYUKI KAMIMOTO (Ministry of International Trade and Industry, Electrotechnical Laboratory, Tsukuba, Japan), and NOBUHIRO TANATSUGU (Tokyo, University, Sagamihara, Japan) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 63-68. refs

The development of latent thermal storage systems for use with solar-dynamic power systems in space applications is discussed, reviewing the results of the authors' recent experimental investigations. The emphasis is on the selection and characterization of phase-change materials for containerized modules. Particular attention is given to materials screening, advanced solar-dynamic power-system concepts, solidification experiments under microgravity, similar experiments under normal gravity, and sounding-rocket experiments. Extensive diagrams, drawings, graphs, photographs, and micrographs are provided. T.K.

A89-15301
THERMAL CYCLING TESTS OF ENERGY STORAGE CANISTERS FOR SPACE APPLICATIONS
R. L. GAY, W. T. LEE, A. G. PARD, and T. H. SPRINGER (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 69-73. refs

Results are reported from thermal cycling tests on two prototype energy-storage canisters for use with solar-dynamic space power systems. A Haynes-188/CaF2-LiF closed-Brayton energy-storage canister and an Ni-201/LiOH organic Rankine canister are described and illustrated with drawings and photographs, and the test results are presented in graphs. Both canisters are found to be viable candidate storage systems. T.K.

A89-15302
SPACE SOLAR CELLS - THE MOVING TARGET
P. A. ILES (Applied Solar Energy Corp., City of Industry, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 75-78.

The development history of solar cells for space power applications is reviewed, with an emphasis on the ways the technology has been modified to meet new requirements. Topics addressed include the early history of solar-cell technology, the design and performance requirements of space missions, prediction of cell degradation rates, specific improvements in cells, advanced solar cells, and hardened designs for military applications. It is concluded that current cell technology and design concepts can produce arrays of 500-1000-kW capacity. T.K.

A89-15305* TRW, Inc., Redondo Beach, CA.
STATUS OF ADVANCED PHOTOVOLTAIC SOLAR ARRAY PROGRAM
RICHARD KURLAND (TRW, Inc., Space and Technology Group, Redondo Beach, CA) and PAUL STELLA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 91-95.
(Contract JPL-957990; NAS7-918)

The current development status of ultralightweight flexible-blanket foldout solar arrays being designed and fabricated under the NASA Advanced Photovoltaic Solar Array (APSA) program is surveyed. The goal of APSA is the construction of a 25-kW array with specific power 300 W/kg (BOL) by the year 2000. Topics discussed here include array configurations, blanket deployment systems, prototype wing-hardware fabrication, component-level test results, solar-cell technologies, and array performance estimates. Diagrams, drawings, graphs, and tables of numerical data are provided. T.K.

A89-15306
THE POTENTIAL OF CUINSE2 AND CDTE FOR SPACE PHOTOVOLTAIC APPLICATIONS
KENNETH ZWEIBEL (Solar Energy Research Institute, Golden, CO) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 97-101. refs

The current development status of CuInSe2 and CdTe solar cells for space power systems is discussed, reviewing the results of recent experimental investigations. Typical performance data are presented in tables and graphs, and it is shown that thin polycrystalline films of these materials offer low cost, reasonable efficiency, high power/weight ratios, excellent radiation hardness, and physical robustness and reliability. T.K.

A89-15307
CONTAMINATION INDUCED DEGRADATION OF SOLAR ARRAY PERFORMANCE
DEAN C. MARVIN, WARREN C. HWANG, GRAHAM S. ARNOLD, and DAVID F. HALL (Aerospace Corp., Los Angeles, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 103-105.
(Contract F04701-85-C-0086)

The solar arrays on GPS Navastars 1-6 have shown anomalous degradation during the 5-year mission life and beyond. The

departure from predicted performance consists of an extra 2.5 percent/yr degradation in excess of the radiation-model estimates. Optical-solar-reflector data from a variety of spacecraft support the idea that contaminants outgassing from the vehicle are photodeposited on the optical surfaces, leading to degradation consistent with the observed behavior of the five Block I vehicles. Author

A89-15309
LIGHTWEIGHT SOLAR ARRAYS FOR HIGH RADIATION ENVIRONMENTS
THEODORE G. STERN (General Dynamics Corp., Space Systems Div., San Diego, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 127-129.

Results are reported from design studies of Si or GaAs solar cells for the high-radiation environments encountered in space missions such as LEO-GEO transfer. Optimum shielding levels for planar and concentrator arrays are calculated, and the results are presented in graphs. It is found that concentrators offer potential weight savings because they require less shielding per W of output power. T.K.

A89-15318
SPACE NUCLEAR POWER STUDIES IN FRANCE - OVERVIEW OF THE ERATO PROGRAM
E. PROUST, F. CARRE, S. CHAUDOURNE, F. GERVAISE, P. KEIRLE (CEA, Centre d'Etudes Nucleaires de Saclay, Gif-sur-Yvette, France) et al. IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 191-196. refs

The ERATO program is reviewed, and a program to study the potential advantages of nuclear power systems over solar dynamic and photovoltaic systems within the 20 kWe power range is described. Specific mass estimations are presented for three candidate systems ranging from 93-105 kg/kW. Alternate design options considered include a derated UO2/Na/SS-650 deg system, a NaK cooled reactor, and a heat pipe radiator. R.R.

A89-15319
ADAPTABILITY OF BRAYTON CYCLE CONVERSION SYSTEMS TO FAST, EPITHERMAL AND THERMAL SPECTRUM SPACE NUCLEAR REACTORS
Z. P. TILLIETTE (CEA, Centre d'Etudes Nucleaires de Saclay, Gif-sur-Yvette, France) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 197-202. CNES-CEA-sponsored research. refs

The application of long-lifetime ZrH moderated reactors associated with a gas cycle as both NaK(Na)-cooled or gas-cooled nuclear heat sources for the Hermes, Columbus and Ariane 5 programs is considered. It is shown that the association of a Brayton cycle with a NaK(Na)-cooled reactor can provide moderate temperature conditioning without a significant performance penalty. The gas-cooled reactor direct cycle system provides better core temperature conditioning than the NaK(Na)-cooled system. R.R.

A89-15320
CERMET-FUELED REACTORS FOR MUILTIMEGAWATT SPACE POWER APPLICATIONS
C. L. COWAN, J. S. ARMIJO, G. B. KRUGER, R. S. PALMER, and J. E. VAN HOOMISSON (General Electric Co., Astro-Space Div., San Jose, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 213-218.
(Contract DE-AC03-86SF-16504)

The cermet-fueled reactor has evolved as a potential power source for a broad range of multimegawatt space applications. The fast spectrum reactor concept can be used to deliver tens of megawatts of electric power for continuous, long term, unattended operation, and hundreds of megawatts of electric power for times exceeding several hundred seconds. Extensive testing of the cermet fuel element has demonstrated that the fuel is capable of operating at very high temperatures under repeated thermal cycling conditions, including transient conditions which approach the multimegawatt burst power requirements. The cermet fuel test performance is reviewed, and an advanced cermet-fueled multimegawatt nuclear reactor is described. Author

A89-15322
A COMPARISON OF THE SNAP AEROSPACE SAFETY PROGRAM WITH CURRENT REQUIREMENTS
RICHARD B. HARTY (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 225-231.

As part of the SNAP-10A flight test program, a comprehensive aerospace nuclear safety program was conducted. The objectives of this program were to evaluate and control the nuclear hazards associated with the transportation, launch, operation, and disposal of space nuclear reactor power systems, and to develop methods and designs to ensure their radiological safety. The program consisted of several analytical and experimental activities that included reactor disintegration, fuel rod reentry burnup, critical configurations, reactor transient behavior, mechanical and thermochemical incidents, end-of-life shutdown, and disposal mode studies. This paper reviews the analytical and experimental activities performed in each of these areas and compares the results with current safety requirements. Author

A89-15323
URANIUM-ZIRCONIUM HYDRIDE FUEL PERFORMANCE IN THE SNAP-DYN SPACE POWER REACTOR
ANDREW G. STADNIK and JOHN P. PAGE (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 233-238. refs

This paper describes the performance characteristics of the uranium-zirconium-hydride (UZrH) fuel system designed for the SNAP-DYN (Systems for Nuclear Auxiliary Power Dynamic) reactor considered for use in space power applications. Results on swelling, hydrogen loss, burnup, and other properties indicate that the UZrH fuel can support the lifetime requirement for the SNAP-DYN design without an extensive test program. Diagrams of the SNAP-DYN reactor and its fuel element are presented. I.S.

A89-15324
SNAP REACTOR REFLECTOR CONTROL SYSTEMS DEVELOPMENT
DONALD F. OWEN (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 239-244. refs

The development of the Systems for Nuclear Auxiliary Power (SNAP) reactor reflector control systems (designed for a severe launch and operational environment) is discussed together with their application for near-term use. The design and the operation of each of the SNAP reactor control systems and of their components are described, and the results of major component testing are presented. It is concluded that the SNAP reactor reflector control systems technology is directly applicaple to the most recent uranium-zirconium-hydride space reactor design, the SMAP-DYN reactor. Design diagrams are included. I.S.

A89-15325
SYNERGISTIC USES OF NERVA DERIVATIVE TECHNOLOGY FOR SPACE POWER
J. W. H. CHI, B. L. PIERCE, and J. F. WETT (Westinghouse Electric Corp., Advanced Energy Systems Div., Madison, PA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 245-248. refs

This paper discusses the key features of the Nuclear Engine Rocket Vehicle Application (NERVA) Derivative Reactor (NDR) and describes the application of this reactor technology to diverse space power missions anticipated. It is pointed out that NDR stands out as the most attractive system for power levels greater than 1 MWe. It can be incorporated in closed or open cycle systems to provide the wide range of power requirements that include megawatts of steady state baseload power or multimegawatts of burst power for weapon sytems or direct propulsive thrust. I.S.

A89-15326
SPACE NUCLEAR POWER STUDIES IN FRANCE - A NEW CONCEPT OF PARTICLE BED REACTOR
B. VRILLON, F. CARRE, and E. PROUST (CEA, Centre d'Etudes Nucleaires de Saclay, Gif-sur-Yvette, France) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 249-254.

An original concept of a gas-cooled epithermal particle bed reactor for driving a direct cycle conversion system with a turbine inlet temperature of 1120 K is being investigated. The reactor and shield, neutronic characteristics, and technology problems of this reactor are described. The energy conversion system and system operating conditions are addressed. C.D.

A89-15327* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SYSTEMS ASPECTS OF A SPACE NUCLEAR REACTOR POWER SYSTEM
L. JAFFE, T. FUJITA, R. BEATTY, P. BHANDARI, E. CHOW, W. DEININGER, R. EWELL, M. GROSSMAN (California Institute of Technology, Jet Propulsion Laboratory, Pasadena), H. BLOOMFIELD, J. HELLER (NASA, Lewis Research Center, Cleveland, OH) et al. IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 255-261.

Various system aspects of a 300-kW nuclear reactor power system for spacecraft have been investigated. Special attention is given to the cases of a reusable OTV and a space-based radar. It is demonstrated that the stowed length of the power system is important to mission design, and that orbital storage for months to years may be needed for missions involving orbital assembly. R.R.

A89-15328
SP-100 SPACE REACTOR POWER SYSTEM SCALABILITY
A. T. JOSLOFF (General Electric Co., Astro-Space Div., King of Prussia, PA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 263-265.

The 1000-kWe reference design for the SP-100 space reactor power system is discussed, and the features of the design which allow for scalability in power level and configuration are reviewed. A major feature allowing design flexibility is the modularity of the power conversion elements. The validation of the basic reactor technology elements is also considered. R.R.

A89-15329
SP-100 NUCLEAR SUBSYSTEM DESIGN
J. D. STEPHEN, I. I. FALUSI, H. CHOE, S. A. SALAMAH, K. L. LEE (General Electric Co., Astro-Space Div., San Jose, CA) et al. IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 267-274. Research supported by the General Electric Co. and DOE.

The nuclear subsystem design for the reference flight system of the SP-100 space reactor power system is discussed. The specific design is a 2.5 MWt reactor to produce 100 kWe. Attention is also given to the shield subsystem, the primary heat transport subsystem, and the reactor instrumentation and control subsystem. B.J.

A89-15331
THERMOELECTRIC ELECTROMAGNETIC PUMP DESIGN FOR SP-100
J. COLLETT, W. KUGLER, U. SINHA, and T. SURJADI (General Electric Co., Astro-Space Div., San Jose, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 281-286. refs

This paper describes the design of the Thermoelectric Electromagnetic (TEM) pump used in the SP-100 space power system. The TEM pump is designed to pump liquid (molten) lithium (Li) coolant in the Primary Heat Transport Subsystem (PHTS) and Heat Rejection Subsystem (HRSS). The pump utilizes advanced Thermoelectric (TE) cells to generate electric current that induces magnetic flux in a Z-shaped magnetic structure. The electric current and magnetic flux pass through the liquid Li perpendicular to each other to create the pumping force. The TE cells are semiconductors located between rectangular ducts connected to the reactor hot PHTS piping and the cooler HRSS piping. The temperature difference (DeltaT) across the cells generates the voltage to power the pump. The design provides a minimum mass, self-regulated pump, with no moving parts and self-powered by an internal temperature gradient. Author

A89-15332
AUTONOMOUS ELECTRICAL POWER SUBSYSTEM
JOSEPH K. MCDERMOTT and JOHN R. STROHL (Martin Marietta Corp., Denver, CO) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 287-292.

The paper describes a study concerning the implementation of certain autonomy features into an existing electric power subsystem (EPS). The EPS of interest is a direct energy, shunt regulated power system providing individual battery charge maintenance. Autonomous fault detection and correction was determined to be feasible through the addition of a microprocessor-based monitor and control system resident in the EPS. B.J.

A89-15338
SOLAR DYNAMIC POWER OPTION FOR THE SPACE STATION
R. V. BOYLE (Allied-Signal Aerospace Co., Fluid Systems Div., Tempe, AZ), M. G. COOMBS (Allied-Signal Aerospace Co., AiResearch Los Angeles Div., CA), and C. T. KUDIJA (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 319-328. refs

Attention is given to the power system architecture for the Electric Power System, a hybrid system consisting of an initial complement of photovoltaic arrays to be later supplemented by solar dynamic power modules. These studies have been supported with designs of a solar dynamic closed Brayton cycle power generation assembly. This paper presents these designs, with updated performance and characteristics. B.J.

A89-15339
TESTS OF HEAT TRANSFER ENHANCEMENT FOR THERMAL ENERGY STORAGE CANISTERS
R. L. GAY, L. H. PIDCOKE, A. I. MUNAIM, and T. H. SPRINGER (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 329-334.

Tests of enhanced heat transfer designs indicate that improvement in heat transfer up to 160 percent can be achieved by adding fins to the internal volume of energy storage canisters for space power systems. This improvement in heat transfer allows for better utilization of the phase change material. B.J.

A89-15340* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE SOLAR DYNAMIC RADIATOR WITH A HISTORICAL PERSPECTIVE
K. L. MCLALLIN (NASA, Lewis Research Center, Cleveland, OH), M. L. FLEMING (LTV Corp., Missiles and Electronics Group, Dallas, TX), F. W. HOEHN, and R. HOWERTON (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 335-340. refs

A historical perspective on pumped loop space radiators provides a basis for the design of the Space Station Solar Dynamic (SD) power module radiator. SD power modules, capable of generating 25 kWe each, are planned for growth Station power requirements. The Brayton (cycle) SD module configuration incorporates a pumped loop radiator that must reject up to 99 kW. The thermal/hydraulic design conditions in combination with required radiator orientation and packaging envelope form a unique set of constraints as compared to previous pumped loop radiator systems. Nevertheless, past program successes have demonstrated a technology base which can be applied to the SD radiator development program to ensure a low risk, low cost system. Author

A89-15341* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THERMAL DISTORTION ANALYSIS OF THE SPACE STATION SOLAR DYNAMIC CONCENTRATOR
JEFFERY J. TRUDELL, KENT S. JEFFERIES (NASA, Lewis Research Center, Cleveland, OH), JOSEPH F. BAUMEISTER (NASA, Lewis Research Center; Analex Corp., Cleveland, OH), and VITHAL DALSANIA (NASA, Lewis Research Center; W. L. Tanksley and Associates, Inc., Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 341-349. Previously announced in STAR as N88-25475. refs

A method was developed to evaluate the thermal distortion of the Space Station Solar Dynamic Concentrator and the effects of thermal distortion on concentrator optical performance. The analytical method includes generating temperature distributions with TRASYS and SINDA models, interfacing the SINDA results with the SINDA-NASTRAN Interface Program (SNIP), calculating thermal distortion with a NASTRAN/PATRAN finite element model, and providing flux distribution maps within the receiver with the ray tracing OFFSET program. Temperature distributions, thermally induced slope errors, and flux distribution maps within the receiver are discussed. Results during a typical orbit indicate that temperatures of the hexagonal panels and triangular facets range between -18 and 99 C (-1 to 210 F), facet rotations are less than 0.2 mrad, and a change in facet radius due to thermal flattening is less than 5 percent. The predicted power loss with thermal distortion effects was less than 0.3 percent. The thermal distortion of the Solar Dynamic concentrator has negligible effect on the flux distribution within the receiver cavity. Author

A89-15342
SOLAR CONCENTRATOR ADVANCED DEVELOPMENT PROGRAM UPDATE
F. H. VALADE (Harris Corp., Government Aerospace Systems Div., Melbourne, FL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 351-356. refs

The power generation system under development for the Space Station, which is a hybrid of solar dynamic and photovoltaic systems, is examined. The Solar Concentrator Advanced Development program is discussed, including the optical and environmental performance requirements, the initial design trade offs, and the design selected for fabrication. R.B.

A89-15343* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ADVANCED SPACE SOLAR DYNAMIC RECEIVERS
HAL J. STRUMPF, MURRAY G. COOMBS (Allied-Signal Aerospace Co., AiResearch Los Angeles Div., Torrance, CA), and DOVIE E. LACY (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 357-365.

A study has been conducted to generate and evaluate advanced solar heat receiver concepts suitable for orbital application with Brayton and Stirling engine cycles in the 7-kW size range. The generated receiver designs have thermal storage capability (to enable power production during the substantial eclipse period which accompanies typical orbits) and are lighter and smaller than state-of-the-art systems, such as the Brayton solar receiver being designed and developed by AiResearch for the NASA Space Station. Two receiver concepts have been developed in detail: a packed bed receiver and a heat pipe receiver. The packed bed receiver is appropriate for a Brayton engine; the heat pipe receiver is applicable for either a Brayton or Stirling engine. The thermal storage for both concepts is provided by the melting and freezing of a salt. Both receiver concepts offer substantial improvements in size and weight compared to baseline receivers. Author

A89-15348* Martin Marietta Aerospace, Denver, CO.
AUTOMATED POWER MANAGEMENT WITHIN A SPACE STATION MODULE
WILLIAM D. MILLER and ELLEN F. JONES (Martin Marietta Corp., Astronautics Group, Denver, CO) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 395-399. NASA-supported research.

An effort to advance and develop techniques and approaches for automation and autonomy in power management and distribution with a Space Station module is described. The applicable breadboard architecture is discussed, summarizing the function partitioning. The breadboard software is briefly addressed, and the breadboard automated operation is described in detail. C.D.

A89-15351* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
THE AUTONOMOUSLY MANAGED POWER SYSTEMS LABORATORY
LOUIS F. LOLLAR and DAVID J. WEEKS (NASA, Marshall Space Flight Center, Huntsville, AL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 415-419.

An overview is given of the Autonomously Managed Power Systems Laboratory (AMPSLAB), the primary focus of space power automation work being performed at NASA/MSFC. The autonomously managed power system is shown. The space power

automation projects associated with AMPSLAB are discussed. C.D.

A89-15352* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SIMULATION TEST BEDS FOR THE SPACE STATION ELECTRICAL POWER SYSTEM
GERALD G. SADLER (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 421-430. Previously announced in STAR as N88-17715.

NASA Lewis Research Center and its prime contractor are respnsible for developing the electrical power system on the Space Station. The power system will be controlled by a network of distributed processors. Control software will be verified, validated, and tested in hardware and software test beds. Current plans for the software test bed involve using real time and nonreal time simulations of the power system. This paper will discuss the general simulation objectives and configurations, control architecture, interfaces between simulator and controls, types of tests, and facility configurations. Author

A89-15353
A USER-FRIENDLY POWER SYSTEM TERMINAL/SUPERVISOR PROGRAM
SUMNER K. HUSHING, III (General Dynamics Corp., Space Systems Div., San Diego, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 431-436.

This paper describes a user-friendly terminal/supervisor program for a 5 kW, 20-kHz ac power system breadboard. The steps of the software development cycle are reviewed, and various constraints and tradeoffs applied to the design and development process are discussed. Suggestions for future versions of this breadboard user interface program are made. C.D.

A89-15355
FAULT TOLERANT POWER CONTROLLER
DENNY D. GUDEA and CHING LEE (TRW, Inc., Space and Technology Group, Redondo Beach, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 441-444.

This paper describes the operation of a triple modular redundant controller based on a radiation-hardened VLSI family of integrated circuits and the associated hardware and software. Fault tolerance is achieved with a multilayered structure of fault detection and correction. Each of the three channels runs on its own clock but whenever an input or output operation is performed, the three channels are resynchronized and the data voted on. This approach allows for different algorithms to run on the three channels, thereby giving protection against programming errors. Most of the errors are corrected at the channel level. C.D.

A89-15356
IMPROVED LOAD SCHEDULING TECHNIQUES
JOHN R. BARTON (Boeing Aerospace Co., Seattle, WA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 445-449.

An improved load scheduling computer code now under development which is to be used in scheduling loads as part of mission planning for a large aerospace power system is discussed. The background and objectives are addressed, including maximum vehicle utilization, even distribution of loads, prioritized load processing, recording load location, and flexible operator control. Requirements concerning general scheduling controls, operating time criteria, and sequenced load groups are considered. The design approach used toward achieving order of load selection, scheduling restrictions, orbit scanning, profile scanning operator modification, energy balance, scheduling speed, data point insertion, data point reduction, and changes in control parameters is discussed. C.D.

A89-15357* Purdue Univ., West Lafayette, IN.
DYNAMIC CHARACTERISTICS OF A 20 KHZ RESONANT POWER SYSTEM - FAULT IDENTIFICATION AND FAULT RECOVERY
O. WASYNCZUK (Purdue University, West Lafayette, IN) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 451-456.
(Contract NAG3-848)

A detailed simulation of a dc inductor resonant driver and receiver is used to demonstrate the transient characteristics of a 20 kHz resonant power system during fault and overload conditions. The simulated system consists of a dc inductor resonant inverter (driver), a 50-meter transmission cable, and a dc inductor resonant receiver load. Of particular interest are the driver and receiver performance during fault and overload conditions and on the recovery characteristics following removal of the fault. The information gained from these studies sets the stage for further work in fault identification and autonomous power system control. Author

A89-15361
MODULAR TRANSFORMER STATE MODEL FOR THE SIMULATION OF HIGH FREQUENCY SPACECRAFT POWER SYSTEMS
BRUCE W. EVANS, L. L. GRIGSBY, and R. M. NELMS (Auburn University, AL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 475-480. Research supported by Auburn University and SDIO. refs
(Contract DNA001-85-C-0183)

A high frequency, lumped parameter model of a power transformer is presented. The model is used to derive a third-order state variable description of the device that is coupled to state variable models of the other power system components. Based on the state model, a digital simulation is conducted using the state transition matrix. The technique is used to simulate a high frequency spacecraft power system which includes a series resonant converter, transformer, transmission line, and resistive-inductive load. Each individual device is modeled as a two-port modular subnetwork with port voltages used as the independent variables. A state variable mathematical description of each device is formulated and numerically simulated using the state transition matrix. The results of the simulation are compared to results from EMTP, a program widely used by the power industry to predict transients. Author

A89-15365
AUTOMATION OF SPACECRAFT POWER ELECTRONICS DESIGN
JESSE E. CHEN and TERRY JURI (Lockheed Missiles and Space Co., Inc., Space Systems Div., Sunnyvale, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 499-502.

This paper describes a visual design program for the automation of spacecraft power electonics design which provides a combination of analytic sophistication and user-friendliness. The program combines the Analog Workbench (AWB) program, which is a user-friendly version of SPICE (Simulation Program with Integrated Circuits Emphasis) with mouse-driven menus and a graphical display of circuits, and the Flowtran, which is a visual design

medium. The principles of the AWB and the Flowtran programs are discussed and their application to power electronics design is demonstrated. Flowcharts and spreadsheets are included. I.S.

A89-15369 Purdue Univ., West Lafayette, IN.
SIMULATION OF A DC INDUCTOR RESONANT INVERTER FOR SPACECRAFT POWER SYSTEMS
O. WASYNCZUK and P. C. KRAUSE (Purdue University, West Lafayette, IN) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 523-528. Research supported by P. C. Krause and Associates, Inc. and NASA.

A detailed simulation of a dc inductor, resonant inverter is described. Computer traces are given and compared with test results for various modes of operation including start-up. A power system including a Lundell alternator, 6-pulse rectifier, dc inductor resonant inverter, Litz cable, and resistive load are simulated to illustrate the performance of the dc inductor resonant inverter in a system environment. Author

A89-15370
POWER SYSTEM DESIGN ANALYSIS COMPUTER PROGRAM
T. L. HERSHEY and HOWARD WEINER (Aerospace Corp., El Segundo, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 529-535. refs

This paper discusses a set of computer programs used in the analyses of spacecraft power systems. These programs allow the designer to vary the many different user and heater load profiles in order to evaluate the size and performance of the batteries, solar array and power processing and distribution equipment. Mission duration, eclipse period duration and frequency of eclipse periods are also input variables. Characteristics and properties of the various components within the power system can be varied. Additionally, the program selects the cover glass thickness to obtain the minimum weight or minimum cost solar array. Power and voltage characteristics, as well as weight, area and volumes are determined at BOL and EOM for the solar array, the batteries, as well as other power system components. The program has run more than 500 separate cases to evaluate either existing or proposed satellite programs. Author

A89-15373
DESIGN, ANALYSIS AND SIMULATION OF THE MAIN BUS DYNAMICS OF SPACECRAFT POWER SYSTEMS
B. H. CHO and J. R. LEE (Virginia Polytechnic Institute and State University, Blacksburg) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 547-553. refs

Small-signal dynamics of the main bus of a spacecraft power system operating in various modes such as the shunt, the snunt/charge, battery charge and discharge modes are analyzed for the regulated bus system using direct-energy-transfer concept. A metnodology to optimize the dyanmics of the bus such as dc regulation, stability and bus impedance using the system's loop gain is presented. Dynamic performances of the bus are simulated with small-signal and large-signal component models using EASY5 program. Author

A89-15376
SPACE STATION PHOTOVOLTAIC POWER MODULE DESIGN
S. T. VOGT and R. A. PROESCHEL (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 567-572.

The Space Station photovoltaic power module is designed to provide 18.75 kW of electrical power. Four such modules will supply the 75 kW of electrical power used on the Phase I station. The function of each module is to generate photovoltaic dc power, store a portion of it for use during eclipse, and convert the net dc output to ac for distribution to users throughout the station by the power management and distribution system. Power is generated by planar solar array assemblies with silicon solar cells. Energy storage is provided by multiple individual pressure vessel Ni-H2 batteries contained in the energy storage assemblies. Provisions for thermal control, pointing and tracking, and dc-to-ac power conversion are also included in the modlue design. Author

A89-15377
SPACE STATION NICKEL-HYDROGEN CELL DESIGN AND DEVELOPMENT
R. J. HAAS and A. K. CHAWATHE (Ford Aerospace Corp., Space Systems Div., Palo Alto, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 573-576.

The use of nickel-hydrogen battery cells in the photovoltaic power subsystem of the Space Station electrical power system is discussed. The cells are expected to provide energy storage for eclipse and contingency operation. The design considerations for these cells are examined, including critical parameters such as nickel electrode void volume, loading levels, current density, chemical and mechanical parameters. Producibility aspects are also considered. R.B.

A89-15378* Ford Aerospace and Communications Corp., Palo Alto, CA.
SPACE STATION BATTERY SYSTEM DESIGN AND DEVELOPMENT
R. J. HAAS, A. K. CHAWATHE, and G. VAN OMMERING (Ford Aerospace Corp., Space Systems Div., Palo Alto, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 577-582.
(Contract NAS3-24666)

The Space Station Electric Power System will rely on nickel-hydrogen batteries in its photovoltaic power subsystem for energy storage to support eclipse and contingency operations. These 81-Ah batteries will be designed for a 5-year life capability and are configured as orbital replaceable units (ORUs), permitting replacement of worn-out batteries over the anticipated 30-year Station life. This paper describes the baseline design and the development plans for the battery assemblies, the battery ORUs and the battery system. Key elements reviewed are the cells, mechanical and thermal design of the assembly, the ORU approach and interfaces, and the electrical design of the battery system. The anticipated operational approach is discussed, covering expected performance as well as the processor-controlled charge management and discharge load allocation techniques. Development plans cover verification of materials, cells, assemblies and ORUs, as well as system-level test and analyses. Author

A89-15380
SPACE STATION SOLAR ARRAY DESIGN AND DEVELOPMENT
R. V. ELMS, K. MIYAGI, and C. A. WINSLOW (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 589-594.

The Space Station solar arrays are required to support a 75 kW bus with eight array wings over a four-year period in low earth orbit. This paper describes the design requirements, the baseline design, and the development test program. B.J.

A89-15381* Texas A&M Univ., College Station.
A SIMULATION MODEL FOR RELIABILITY EVALUATION OF SPACE STATION POWER SYSTEMS
C. SINGH, A. D. PATTON, MUDIT KUMAR (Texas A & M University, College Station), and H. WAGNER (NASA, Johnson Space Center, Houston, TX) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 595-598.
(Contract NAG9-192)

A detailed simulation model for the hybrid Space Station power system is presented which allows photovoltaic and solar dynamic power sources to be mixed in varying proportions. The model considers the dependence of reliability and storage characteristics during the sun and eclipse periods, and makes it possible to model the charging and discharging of the energy storage modules in a relatively accurate manner on a continuous basis. B.J.

A89-15382
OVERVIEW OF POWER MANAGEMENT SYSTEM FUNCTIONS FOR SPACECRAFT POWER SYSTEMS
GERALD B. SHEBLE (Auburn University, AL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 599-602. refs

A conceptual framework for computer directed monitoring, assessment and control of a spacecraft power system is presented. The five principal operating modes are defined. The basic structure is divided into the functions that will monitor and assess the power system, the functions that will control the power system and the functions that will diagnose the power system both before and after equipment failures. The basis for these functions is the extensive experience with monitoring, assessment and control of terrestiral power systems with Energy Mangement Systems. All applications are computer based. However, some manual intervention may be required for degraded operation. A statement of the function methodology, the expected computer requirements, the expected periodicities and the operating restrictions are provided. The difference between power management for spacecraft power systems and energy management for terrestrial power systems are compared for each major function. The initial design of a Power Management System (PMS) for spacecraft power systems is proposed. Author

A89-15384
THE IMPACT OF THE UTILITY POWER SYSTEM CONCEPT ON SPACECRAFT ACTIVITY SCHEDULING
DANIEL L. BRITT, JOHN R. GOHRING, and AMY L. GEOFFROY (Martin Marietta Corp., Bethesda, MD) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 621-626.

Basic issues in scheduling are discussed with attention given to the utility power system concept as it applies to a Space Station module. A power system breadboard at Marshall Space Flight Center which implements the concept and includes a high degree of automation is described. The ways in which the utility power system interacts with the scheduling function within mission operations are considered. K.K.

A89-15385
INTEGRATED CONTROL OF THE SPACE STATION ELECTRICAL POWER SYSTEM
W. H. ALLEN (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 627-630.

The overall integrated control of the Space Station electrical power system is discussed, with emphasis on the integration of new features to achieve an automatic and autonomous space power utility. The control hardware configuration is discussed, along with the location of the various control modules. Integrated control algorithms automatically correct such system disturbances as network configuration changes and load circuit overloads. R.R.

A89-15386
STABILITY CONSIDERATIONS FOR THE RESONANT POWER PROCESSOR INTERFACES IN THE SPACE STATION APPLICATION
JAMES W. MILDICE (General Dynamics Corp., Space Systems Div., San Diego, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 631-636.

The following stability regimes are addressed: (1) the dc interface at solar array, and (2) the ac interface between the inverters, power transmission bus, and loads. Consideration is given to the technical questions concerning the use of resonant high-frequency power system technology in the Space Station type application. The highly-reactive low KVAR loads presented by unloaded buses do not present a stability problem. K.K.

A89-15387* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
POWER COMPONENTS FOR THE SPACE STATION 20-KHZ POWER DISTRIBUTION SYSTEM
DAVID D. RENZ (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 637-641. Previously announced in STAR as N88-21374. refs

Since 1984, NASA Lewis Research Center was developing high power, high frequency space power components as part of The Space Station Advanced Development program. The purpose of the Advanced Development program was to accelerate existing component programs to ensure their availability for use on the Space Station. These components include a rotary power transfer device, remote power controllers, remote bus isolators, high power semiconductor, a high power semiconductor package, high frequency-high power cable, high frequency-high power connectors, and high frequency-high power transformers. All the components were developed to the prototype level and will be installed in the Lewis Research Center Space Station power system test bed. Author

A89-15388* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
MULTI-HUNDRED KILOWATT ROLL RING ASSEMBLY EVALUATION RESULTS
DAVID D. RENZ (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 643-648. Previously announced in STAR as N88-21375.

NASA Lewis Research Center has been evaluating low loss multi-hundred-kilowatt Roll Ring assemblies (an 8 circuit and a 4 circuit) for use on Space Station as the rotating joint power transfer device. In this device ac or dc power is transferred across the rotating joint through compressed rotating flexures. Results and conclusions of the evaluation program are presented. Author

A89-15389* General Dynamics Corp., San Diego, CA.
AC BIDIRECTIONAL MOTOR CONTROLLER
K. SCHREINER (General Dynamics Corp., Space Systems Div., San Diego, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 649-653. NASA-supported research. refs

Test data are presented and the design of a high-efficiency motor/generator controller at NASA-Lewis for use with the Space Station power system testbed is described. The bidirectional motor driver is a 20 kHz to variable frequency three-phase ac converter that operates from the high-frequency ac bus being designed for the Space Station. A zero-voltage-switching pulse-density-modulation technique is used in the converter to shape the low-frequency output waveform. K.K.

A89-15390 Virginia Polytechnic Inst. and State Univ., Blacksburg.
EFFECTS OF LOAD ON THE PERFORMANCE OF THE MAPHAM RESONANT INVERTER
FU-SHENG TSAI and FRED C. LEE (Virginia Polytechnic Institute and State University, Blacksburg) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 655-661. Research supported by the Rockwell International Corp. and NASA. refs

The Mapham resonant inverter, proposed as a main driver-inverter in the 20 kHz, ac distribution system for a Space Station, is characterized with various types of load. The effects of load on the inverter's output regulation, harmonic distortions, and dynamic transience are investigated. Failure mode of operation leading to unbounded circuit currents is discussed. A simple control logic is suggested to prevent such a catastrophe. To minimize the inverter's output impedance, a series output capacitor is proposed with an optimal value determined analytically. Author

A89-15391* Purdue Univ., West Lafayette, IN.
SIMULATION AND CONTROL OF A 20 KHZ SPACECRAFT POWER SYSTEM
O. WASYNCZUK and P. C. KRAUSE (Purdue University, West Lafayette, IN) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 663-669.
(Contract NAS3-25119)

A detailed computer representation of four Mapham inverters connected in a series, parallel arrangement has been implemented. System performance is illustrated by computer traces for the four Mapham inverters connected to a Litz cable with parallel resistance and dc receiver loads at the receiving end of the transmission cable. Methods of voltage control and load sharing between the inverters are demonstrated. Also, the detailed computer representation is used to design and to demonstrate the advantages of a feed-forward voltage control strategy. It is illustrated that with a computer simulation of this type, the performance and control of spacecraft power systems may be investigated with relative ease and facility. Author

A89-15393
AN ANALYSIS OF THE EFFECTS OF EXTERNAL HEATING ON THE SP-100 SYSTEM RADIATOR HEAT PIPES
MOHAMED S. EL-GENK and JONG T. SEO (New Mexico, University, Albuquerque) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 673-680. Research supported by the University of New Mexico. refs

A two-dimensional transient heat pipe model is employed to investigate the survivability of a simulated SP-100 heat pipe. Although it is shown that heat pipe failure due to external thermal exposure is unlikely, a reverse operation which will transport a fraction of the external heat to the lithium in the secondary coolant loop will temporarily occur. It is found that a full external exposure as low as 17 kW/sq m lasting for more than 6.5 seconds can reverse the operation of the radiator's heat pipes. R.R.

A89-15395
ATHENA SIMULATION EXAMINING THE SURVIVABILITY OF A SPACE REACTOR AFTER A LOSS OF COOLANT ACCIDENT
PAUL A. ROTH and REX W. SHUMWAY (EG & G Idaho National Engineering Laboratory, Idaho Falls) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 685-689. refs
(Contract DE-AC07-76ID-01570)

The Advanced Thermal Hydraulic Energy Network Analyzer (ATHENA) code was used to simulate a loss-of-coolant accident (LOCA) in a conceptual space reactor design. ATHENA provides the capability of simulating the thermal-hydraulic behavior of the wide variety of systems which are being considered for use in space reactors. Flow loops containing any one of several available working fluids may interact through thermal connections with other loops containing the same or a different working fluid. The code can be used to model special systems such as: heat pipes, point reactor kinetics, plant control systems, turbines, valves, and pumps. This work demonstrates the application of the thermal radiation model which has been recently incorporated into ATHENA and verifies the need for supplemental reactor cooling to prevent reactor fuel damage in the event of a LOCA. Author

A89-15403* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
POWER TRANSMISSION STUDIES FOR TETHERED SP-100
DAVID J. BENTS (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 733-741. Previously announced in STAR as N88-21251. refs

The tether and/or transmission line connecting the SP-100 to Space Station presents some unorthodox challenges in high voltage engineering, power transmission, and distribution. The line, which doubles as a structural element of this unusual spacecraft, will convey HVDC from SP-100 to the platform in low Earth orbit, and environment where the local plasma is sufficient to cause breakdown of exposed conductors at potentials of only a few hundred volts. Its anticipated several years operation, and continuously accumulating exposure to meteoroids and debris, raises an increasing likelihood that mechanical damage, including perforation, will be sustained in service. The present concept employs an array of gas insulated solid wall aluminum coaxial tubes; a conceptual design which showed basic feasibility of the SP-100 powered Space Station. Practical considerations of launch, deployment and assembly have led to investigation of reel deployable, dielectric insulated coaxial cables. To be competitive, the dielectric would have to operate reliably in a radiation environment under electrical stresses exceeding 50 kV/cm. The SP-100 transmission line high voltage interfaces are also considered. Author

A89-15405
HIGH VOLTAGE BREAKDOWN IN THE SPACE ENVIRONMENT
L. B. GORDON (Auburn University, AL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 749-754. SDIO-supported research.
(Contract DNA001-85-C-0183)

Recent results and the direction of current research at the Space Power Institute at Auburn University concerning some of the high-voltage insulation issues in the space environment are discussed. A high-vacuum space simulation chamber with capability for rapid pumpdown is described, as is a high-vacuum space simulation chamber for measuring the Paschen curve breakdown characteristics of gas mixtures. The rapid outgassing characteristics of a number of materials have been measured, leading to the

conclusion that outgassing dominates the local region for materials newly exposed to a vacuum environment. C.D.

A89-15411
SPACECRAFT ELECTRICAL POWER SYSTEMS LESSONS LEARNED
AMY C. REISS GERSON (Boeing Aerospace Co., Seattle, WA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 785-788. refs

This paper presents results of a survey of space power systems experts from industry, government, and academia concerning solutions to power systems problems. The topics addressed include systems engineering, solar arrays, arcing and corona discharge, plasma interaction, solar array deployment, power electronics, batteries, and power distribution wiring. Problems and concerns are reviewed for program phases starting with design, through development, testing, and flight operations. C.D.

A89-15413
AUGMENTATION OF THE MMS MPS POWER CAPABILITIES
P. R. K. CHETTY (Fairchild Space Co., Germantown, MD) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 793-797. refs

The current Modular Power Subsystem (MPS) Module or Power Module developed by NASA for the Multimission Modular Spacecraft (MMS) for NASA and DoD missions is based upon early 1970s technology, and the maximum performance expected from it is limited due to component and design technology. This paper explores a segmentation approach to enhance the power capabilities of the power subsystem. Solar array considerations are addressed. C.D.

A89-15415* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ADVANCED SENSIBLE HEAT SOLAR RECEIVER FOR SPACE POWER
TIMOTHY J. BENNETT (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH) and DOVIE E. LACY (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 4. New York, American Society of Mechanical Engineers, 1988, p. 211-216. Previously announced in STAR as N88-21249.

NASA Lewis, through in-house efforts, has begun a study to generate a conceptual design of a sensible heat solar receiver and to determine the feasibility of such a system for space power applications. The sensible heat solar receiver generated in this study uses pure lithium as the thermal storage medium and was designed for a 7 kWe Brayton (PCS) operating at 1100 K. The receiver consists of two stages interconnected via temperature sensing variable conductance sodium heat pipes. The lithium is contained within a niobium vessel and the outer shell of the receiver is constructed of third generation rigid, fibrous ceramic insulation material. Reradiation losses are controlled with niobium and aluminum shields. By nature of design, the sensible heat receiver generated in this study is comparable in both size and mass to a latent heat system of similar thermal capacitance. The heat receiver design and thermal analysis were conducted through the combined use of PATRAN, SINDA, TRASYS, and NASTRAN software packages. Author

A89-15416* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
RAY TRACING OPTICAL ANALYSIS OF OFFSET SOLAR COLLECTOR FOR SPACE STATION SOLAR DYNAMIC SYSTEM
KENT S. JEFFERIES (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 4. New York, American Society of Mechanical Engineers, 1988, p. 225-232. Previously announced in STAR as N88-22080.

OFFSET, a detailed ray tracing computer code, was developed at NASA Lewis Research Center to model the offset solar collector for the Space Station solar dynamic electric power system. This model traces rays from 50 points on the face of the sun to 10 points on each of the 456 collector facets. The triangular facets are modeled with spherical, parabolic, or toroidal reflective surface contour and surface slope errors. The rays are then traced through the receiver aperture to the walls of the receiver. Images of the collector and of the sun within the receiver produced by this code provide insight into the collector receiver interface. Flux distribution on the receiver walls, plotted by this code, is improved by a combination of changes to aperture location and receiver tilt angle. Power loss by spillage at the receiver aperture is computed and is considerably reduced by using toroidal facets. Author

A89-15418
SOLAR THERMODYNAMIC POWER GENERATION EXPERIMENT ON SPACE FLYER UNIT
NOBUHIRO TANATSUGU (Tokyo, University, Sagamihara, Japan) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 4. New York, American Society of Mechanical Engineers, 1988, p. 239-242.

An account is given of the orbital experiment planned for the solar thermodynamic power system of the Japanese Space Flyer Unit (SFU). The power system encompasses a solar radiation collector, a thermal storage system, and a space radiator; attention is given to their reliability and durability. An examination is made of the ways in which vibration and inertia due to the moving parts of the system affect the SFU's payload. O.C.

A89-15419
ALTERNATIVE HEAT PUMP CONFIGURATIONS
R. P. SCARINGE, J. A. BUCKMAN, L. R. GRZYLL (Mainstream Engineering Corp., Melbourne, FL), E. T. MAHEFKEY, and J. E. LELAND (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 4. New York, American Society of Mechanical Engineers, 1988, p. 333-338. refs
(Contract F33615-87-C-2797; F33615-87-C-2841)

This paper discusses the development of two hermetically sealed thermally driven heat pump configurations for spacecraft. Both heat pumps use a Rankine-powered vapor-compression heat-pump configuration, although alternative designs are discussed in the paper. Another aspect is the identification of new working fluids for these systems. Author

A89-15827* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
GAAS MMIC ELEMENTS IN PHASED-ARRAY ANTENNAS
REGIS F. LEONARD (NASA, Lewis Research Center, Cleveland, OH) IN: Optoelectronic signal processing for phased-array antennas; Proceedings of the Meeting, Los Angeles, CA, Jan. 12, 13, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 72-79. refs

Over the last six years NASA Lewis Research Center has carried out a program aimed at the development of advanced monolithic microwave integrated circuit technology, principally for use in phased-array antenna applications. Arising out of the Advanced Communications Technology Satellite (ACTS) program, the initial targets of the program were chips which operated at 30 and 20 GHz. Included in this group of activities were monolithic power modules with an output of 2 watts at GHz, variable phase shifters at both 20 and 30 GHz, low noise technology at 30 GHz, and a fully integrated (phase shifter, variable gain amplifier, power amplifier) transmit module at 20 GHz. Subsequent developments are centered on NASA mission requirements, particularly Space

Station communications systems and deep space data communications. Author

A89-17625
SPACE STATION ENERGY STORAGE SYSTEM DEVELOPMENT
ROBERT O. PRICE Aerospace Engineering (ISSN 0736-2536), vol. 8, Nov. 1988, p. 17-21.

As currently envisioned, NiH2 battery technology and active thermal management will furnish the NASA Space Station's Energy Storage Assembly (ESA) system with low technical and development risk, commonality with other Station and platform electrical power system elements, operational flexibility, and high reliability. Attention is presently given to the ESA's Thermal Control System design, as well as to the rationale for the use of an NiH2 battery system rather than one based on NiCd cells or regenerative fuel cells. O.C.

A89-17640#
INTEGRATED ENERGY AND MEDIA SUPPLY CONCEPTS FOR LONG TERM SPACE MISSIONS
W. SCHWARZOTT, G. REICH, and W.-J. DENNER (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p. refs
(IAF PAPER 88-034)

In order to minimize the operational cost of future long-term manned space missions, an integrated regenerative energy and media supply system (EMSS) for spacecraft and Space Station is proposed. Based on an H2/O2-technology the first step into a regenerative EMSS could be the integration of the subsystems energy supply, environmental control and life support as well as attitude and orbit control. Further extension of such a system may also comprise the nutrition system including then further elements as N2 and C. Electrolyzer and fuel cell systems play an important role with EMSS as energy converter while solar dynamic energy supply systems may offer thermal energy in parallel to electricity. Simultaneous availability of thermal and electric energy including adequate storage facilities will form an optimum basis to a variety of different chemical recycling processes as well as media and energy conversion. The motivation for such a technology is presented, the technical characteristics of subsystems technology are summarized and the first approaches of possible concepts are developed. Step by step solutions seem possible so that pilot test plants of low degree of integration may be investigated already in the course of the planned Space Station. Author

A89-17727#
COMPARISON OF A CASSEGRAIN MIRROR CONFIGURATION TO A STANDARD PARABOLIC DISH CONCENTRATOR CONFIGURATION FOR A SOLAR-DYNAMIC POWER SYSTEM
JUERGEN BLUMENBERG and WILFRIED ZOERNER (Muenchen, Technische Universitaet, Munich, Federal Republic of Germany) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 9 p.
(IAF PAPER 88-209)

Two possible insolation-collector configurations have been analyzed and optimized for application to a solar-dynamic large spacecraft power system: a 'standard' collector, and a Cassegrain collector. The standard configuration is defined by the paraboloid's rim angle only, while the Cassegrain is described by both the primary mirror's paraboloid rim angle and the secondary mirror's hyperboloid position. An optimization of maximum concentration, optical efficiency, and thermal efficiency, has established that collector performance is virtually independent of concentration for values of 1000-2000. O.C.

A89-17729#
EXPERIMENTAL SYSTEM FOR MICROWAVE POWER TRANSMISSION FROM SPACE TO EARTH
R. AKIBA (Tokyo, University, Japan), M. SHIGEHARA, and Y. TORIYAMA (Toshiba Corp., Space Div., Japan) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p.
(IAF PAPER 88-218)

A simplified version of the Energy Storable Orbital Power Station (ESOPS) will be available for the experimental transmission of energy by microwaves from orbital space to the earth surface. In order to maximize ESOPS orbital mass (up to 10 tons), a 500-km orbital altitude has been chosen. The ESOPS will transmit microwave power during a visible period of 5-10 min. The rectennas receiving the microwave power from ESOPS are distributed in a circle of approximately 16 percent diameter; 90-percent power collection is anticipated. O.C.

A89-17752#
SOLAR ARRAY PADDLE WITH LIGHTWEIGHT LATTICE PANEL
H. HASHIMOTO (National Space Development Agency of Japan, Ibaraki), T. AKAEDA, M. IWAKAMI, K. MATSUMURA, and Y. KAWAI (Toshiba Corp., Kawasaki, Japan) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 9 p.
(IAF PAPER 88-271)

A very efficient solar array paddle has been developed for large scale satellites in communication and/or direct-broadcasting missions using higher electrical power up to ten kilowatt range with lighter weight requirements. A power-to-mass ratio of the paddle was improved by employing an ultrathin silicon solar cell of 50-micron thickness and the Lightweight Lattice Panel (LLP)>. This paper describes the concept of the paddle configuration, details the constituent parts, and summarizes development test results. Author

A89-20575
SPACE STATION POWER MANAGEMENT AND DISTRIBUTION SYSTEM DEVELOPMENT
ROBERT O. PRICE Aerospace Engineering (ISSN 0736-2536), vol. 8, Dec. 1988, p. 17-21.

The NASA Space Station's Power Management and Distribution (PMAD) system, which is one of three major Electrical Power System elements, must furnish reliable, automatic operation and autonomy characterized by user-friendliness, adaptability to load type and size changes, and capacity for future incremental growth. Attention is presently given to the architectures of the external power distribution and control assembly and the power management data bus architecture; a ring-distribution PMAD architecture was found to be 30 percent lighter than an alternative radial system, due to its inherent, multiple-path interconnectedness. O.C.

A89-23146* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
USE OF PURE NICKEL AND LIOH FOR THERMAL ENERGY STORAGE
J. D. WHITTENBERGER (NASA, Lewis Research Center, Cleveland, OH) Journal of Materials Engineering (ISSN 0931-7058), vol. 10, Dec. 1988, p. 247-258. refs

The solid to liquid phase transformation of LiOH has been proposed as an ideal candidate thermal energy storage media for a Rankine Cycle powered electrical generation unit envisioned in Space Station based solar dynamic systems. Due to the corrosive nature of molten hydroxides, long term containment of LiOH is of concern. Pure nickel is thought to be a suitably resistant material, and a program has been instituted to measure the effects of prolonged exposure of liquid and gaseous LiOH on the mechanical properties of pure nickel alloys. Results to date indicate that negligible weight and thickness changes occurred in Ni alloys exposed to LiOH for as long as 2500 hr at 775 K, and essentially no difference in 77-900 K tensile properties could be detected between LiOH exposed and vacuum annealed Ni specimens. Although there was little sign of outward damage, microstructural examination revealed that all hydroxide contaminated tensile test specimens had surface connected intergranular cracks along the gage lengths. Two other potential problems, which have strong implications with respect to a LiOH/Ni energy storage system,

were also noted during the corrosion experiments. In particular stress corrosion cracking of weld joints in pressurized vessel and permeation of hydrogen through nickel were observed. Author

A89-23280* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SPACE ELECTROCHEMICAL RESEARCH AND TECHNOLOGY CONFERENCE, CLEVELAND, OH, APR. 14-16, 1987, PROCEEDINGS
LAWRENCE H. THALLER, ED. (NASA, Lewis Research Center, Cleveland, OH) Conference sponsored by NASA. Journal of Power Sources (ISSN 0378-7753), vol. 22, March-Apr. 1988, 259 p. Previously announced in STAR as N87-29914.

The conference provided a forum to assess critical needs and technologies for the NASA electrochemical energy conversion and storage program. It was aimed at providing guidance to NASA on the appropriate direction and emphasis of that program. A series of related overviews were presented in the areas of NASA advanced mission models (space stations, low and geosynchronous Earth orbit missions, planetary missions, and space transportation). Papers were presented and workshops conducted in a variety of technical areas, including advanced rechargeables, advanced concepts, critical physical electrochemical issues, and modeling. Author

A89-23281* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
STATUS OF THE SPACE STATION POWER SYSTEM
COSMO R. BARAONA and DEAN W. SHEIBLEY (NASA, Lewis Research Center, Cleveland, OH) (NASA, Space Electrochemical Research and Technology Conference, Cleveland, OH, Apr. 14-16, 1987) Journal of Power Sources (ISSN 0378-7753), vol. 22, March-Apr. 1988, p. 195-203. Previously announced in STAR as N87-29915.

The major requirements and guidelines that affect the manned Space Station configuration and the power systems are explained. The evolution of the Space Station power system from the NASA program development feasibility phase through the current preliminary design phase is described. Several early station concepts are described and linked to the present concept. The recently completed phase B tradeoff study selections of photovoltaic system technologies are described. The present solar dynamic and power management and distribution systems are also summarized for completeness. Author

A89-23282
A VIEW FROM THE AIAA - INTRODUCTION OF NEW ENERGY STORAGE TECHNOLOGY INTO ORBITAL PROGRAMS
CHARLES BADCOCK (Aerospace Corp., Los Angeles, CA) (NASA, Space Electrochemical Research and Technology Conference, Cleveland, OH, Apr. 14-16, 1987) Journal of Power Sources (ISSN 0378-7753), vol. 22, March-Apr. 1988, p. 205-210. Research supported by the Aerospace Corp.

R&D strategies for space power-system energy-storage facilities are discussed, with an emphasis on safety and reliability issues. It is pointed out that these issues must be addressed at an early stage of a project to avoid fully developing a technology that can never be made flight-qualified. Also stressed are the needs for frequent reviews of both the basic technological status and application-specific factors (failure modes and effects analysis), rigorous prototype testing simulating the actual operational environment, and service-life testing within an assured-performance envelope. T.K.

A89-25204#
SOLID-SOLID PHASE CHANGE THERMAL STORAGE APPLICATION TO SPACE-SUIT BATTERY PACK
CHANG H. SON and JEFFREY H. MOREHOUSE (South Carolina, University, Columbia) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 6 p. refs
(AIAA PAPER 89-0240)

High cell temperatures are seen as the primary safety problem in the Li-BCX space battery. The exothermic heat from the chemical reactions could raise the temperature of the lithium electrode above the melting temperature. Also, high temperature causes the cell efficiency to decrease. Solid-solid phase-change materials were used as a thermal storage medium to lower this battery cell temperature by utilizing their phase-change (latent heat storage) characteristics. Solid-solid phase-change materials focused on in this study are neopentyl glycol and pentaglycerine. Because of their favorable phase-change characteristics, these materials appear appropriate for space-suit battery pack use. The results of testing various materials are reported as thermophysical property values, and the space-suit battery operating temperature is discussed in terms of these property results. Author

A89-25738
AC SYSTEM-PLASMA INTERACTIONS
R. P. STILLWELL, N. J. STEVENS, G. K. CRAWFORD, S. R. STRADER, and J. R. VALLES (TRW, Inc., Space and Defense Sector, Redondo Beach, CA) (IEEE, DNA, NASA, and DOE, Annual Conference on Nuclear and Space Radiation Effects, 25th, Portland, OR, July 12-15, 1988) IEEE Transactions on Nuclear Science (ISSN 0018-9499), vol. 35, Dec. 1988, pt. 1, p. 1394-1399. refs

An experimental study was conducted to determine the interaction between space plasma and an ac power system. The results indicate that there is resonance coupling at low frequencies. This resonance coupling results in increased current collection by an ac system compared to a similar dc system. I.E.

A89-27846
MODULAR PERFORMANCE SIMULATION OF SPACECRAFT FUEL CELL SYSTEMS INCLUDING APPLICATION FOR HERMES
MARKUS ROTHMEYER, RALF SIMON, and UWE BENZ (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 13 p. Research supported by ESA. refs
(SAE PAPER 881046)

A modular simulation program called SANFU (System ANalyzer for FUel cells) has been developed and applied to the performance of fuel cell systems considered primarily for the Hermes manned spaceplane. Three different fuel cell systems are included in the standard program: immobile electrolyte, mobile electrolyte, and ion-exchange-membrane fuel cells. The program was tested for the Hermes fuel cell system simulation. Results are shown of simulations for different load cases, transient boundary conditions, and different control concepts. The future application feasibility of SANFU to ECLS systems simulation within Hermes and Columbus is also discussed. S.A.V.

A89-27897* Ergenics, Inc., Wyckoff, NJ.
A FUEL CELL ENERGY STORAGE SYSTEM FOR SPACE STATION EXTRAVEHICULAR ACTIVITY
MATTHEW J. ROSSO, JR., OTTO J. ADLHART (Ergenics Power Systems, Inc., Wyckoff, NJ), and JOSE A. MARMOLEJO (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 9 p.
(SAE PAPER 881105)

The development of a fuel cell energy storage system for the Space Station Extravehicular Mobility Unit (EMU) is discussed. The ion-exchange membrane fuel cell uses hydrogen stored as a metal hydride. Several features of the hydrogen-oxygen fuel cell are examined, including its construction, hydrogen storage, hydride recharge, water heat, water removal, and operational parameters. R.B.

A89-27899
DYNAMIC POWER CONVERSION CYCLE COMPONENT DEMONSTRATIONS
RICHARD J. PEARSON (Grumman Space Systems, Bethpage, NY) SAE, Intersociety Conference on Environmental Systems,

18th, San Francisco, CA, July 11-13, 1988. 15 p. refs
(Contract F04701-85-C-0090)
(SAE PAPER 881108)

An evaluation has been made of two competing alternative thermodynamic cycles for spacecraft electrical energy generation in the 1-10 kW(e) range on the basis of either solar or nuclear energy inputs: the organic Rankine cycle, and the closed Brayton cycle. These powerplants represent a 20-30 percent cycle efficiency improvement in the case of solar energy over thermoelectric couple and solar cell systems, and a 400-500 percent increase in conversion efficiency over thermoelectric systems in the case of nuclear energy. Attention is given to turbine shaft bearing designs and their performance. O.C.

A89-29111
SOLAR ENGINEERING - 1988; PROCEEDINGS OF THE TENTH ANNUAL ASME SOLAR ENERGY CONFERENCE, DENVER, CO, APR. 10-14, 1988

L. M. MURPHY, ED. (Solar Energy Research Institute, Golden, CO) and T. R. MANCINI, ED. (Sandia National Laboratories, Albuquerque, NM) Conference sponsored by ASME. New York, American Society of Mechanical Engineers, 1988, 560 p. For individual items see A89-29112 to A89-29123.

Various papers on solar engineering are presented. The general topics addressed include: testing and measurements; fundamentals of solar energy systems; solar ponds; alternative heating and cooling technologies; utility-oriented conceptual design studies for central receivers. Also discussed are: testing and advanced concepts for central receivers; distributed receiver systems; components: concentrators, receivers, and engines; solar dynamic space power; energy conversion in buildings; photovoltaic components and systems; and simulation, modeling, and optimization. C.D.

A89-29112#
DESIGN OF AN ADVANCED SOLAR STIRLING CONVERSION SYSTEM FOR TERRESTRIAL POWER GENERATION

A. BROWN, M. DHAR, and N. VITALE (Mechanical Technology, Inc., Latham, NY) IN: Solar engineering - 1988; Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, CO, Apr. 10-14, 1988. New York, American Society of Mechanical Engineers, 1988, p. 281-287.

This paper describes the conceptual design of a free-piston Stirling engine/linear alternator system to be used as the solar-to-electric converter on a point-focused solar collector. The cost, performance, and life tradeoffs are described. The predicted design and off-design performance and the operational aspects of the design are addressed. C.D.

A89-29113*# Martin Marietta Energy Systems, Inc., Oak Ridge, TN.
THERMAL ANALYSIS OF HEAT STORAGE CANISTERS FOR A SOLAR DYNAMIC, SPACE POWER SYSTEM

R. P. WICHNER, A. D. SOLOMON, J. B. DRAKE, and P. T. WILLIAMS (Martin Marietta Energy Systems, Inc., Oak Ridge, TN) IN: Solar engineering - 1988; Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, CO, Apr. 10-14, 1988. New York, American Society of Mechanical Engineers, 1988, p. 319-328. Previously announced in STAR as N88-22075. refs
(Contract DE-AC05-84OR-21400; NASA ORDER C-30001-J)

A thermal analysis was performed of a thermal energy storage canister of a type suggested for use in a solar receiver for an orbiting Brayton cycle power system. Energy storage for the eclipse portion of the cycle is provided by the latent heat of a eutectic mixture of LiF and CaF2 contained in the canister. The chief motivation for the study is the prediction of vapor void effects on temperature profiles and the identification of possible differences between ground test data and projected behavior in microgravity. The first phase of this study is based on a two-dimensional, cylindrical coordinates model using an interim procedure for describing void behavor in 1-g and microgravity. The thermal analysis includes the effects of solidification front behavior, conduction in liquid/solid salt and canister materials, void growth and shrinkage, radiant heat transfer across the void, and convection in the melt due to Marangoni-induced flow and, in 1-g, flow due to density gradients. A number of significant differences between 1-g and o-g behavior were found. This resulted from differences in void location relative to the maximum heat flux and a significantly smaller effective conductance in 0-g due to the absence of gravity-induced convection. Author

A89-29114*# University of South Florida, Tampa.
EVALUATION OF ALTERNATIVE PHASE CHANGE MATERIALS FOR ENERGY STORAGE IN SOLAR DYNAMIC APPLICATIONS

R. A. CRANE (South Florida, University, Tampa, FL) and M. O. DUSTIN (NASA, Lewis Research Center, Cleveland, OH) IN: Solar engineering - 1988; Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, CO, Apr. 10-14, 1988. New York, American Society of Mechanical Engineers, 1988, p. 329-334. refs

The performance of fluoride salt and metallic thermal energy storage materials are compared in terms of basic performance as applied to solar dynamic power generation. Specific performance considerations include uniformity of cycle inlet temperature, peak cavity temperature, TES utilization, and system weights. Also investigated were means of enhancing the thermal conductivity of the salts and its effect on the system performance. Author

A89-29115#
SPACE DEPLOYABLE MEMBRANE CONCENTRATORS FOR SOLAR DYNAMIC POWER SYSTEMS

K. J. BENINGA and B. L. BUTLER (Science Applications International Corp., San Diego, CA) IN: Solar engineering - 1988; Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, CO, Apr. 10-14, 1988. New York, American Society of Mechanical Engineers, 1988, p. 335-342. refs

The use of membrane concentrators as an alternative to more rigid segmented concentrators for solar dynamic power applications in space is examined. A quasi-isotropic preformed parabolic dish composite membrane which can be folded or rolled up for transport to space for subsequent deployment is described. Two structural support systems have been developed for the deployment and support of the membranes in space. The materials selection and membrane fabrication are discussed. C.D.

A89-29117*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
THE DEVELOPMENT OF AN ADVANCED GENERIC SOLAR DYNAMIC HEAT RECEIVER THERMAL MODEL

Y. C. WU, E. J. ROSCHKE, and L. KOHOUT (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Solar engineering - 1988; Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, CO, Apr. 10-14, 1988. New York, American Society of Mechanical Engineers, 1988, p. 353-360. refs

An advanced generic solar dynamic heat receiver thermal model under development which can analyze both orbital transient and orbital average conditions is discussed. This model can be used to study advanced receiver concepts, evaluate receiver concepts under development, analyze receiver thermal characteristics under various operational conditions, and evaluate solar dynamic system thermal performances in various orbit conditions. The model and the basic considerations that led to its creation are described, and results based on a set of baseline orbit, configuration, and operational conditions are presented to demonstrate the working of the receiver model. C.D.

A89-29118#
TECHNOLOGY UPDATE - SOLAR DYNAMIC ORGANIC RANKINE CYCLE POWER SYSTEM

D. W. CHAUDOIR, V. N. HAVENS, and G. R. HEIDENREICH (Sundstrand Corp., Sundstrand Energy Systems Div., Rockford, IL) IN: Solar engineering - 1988; Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, CO, Apr. 10-14, 1988.

New York, American Society of Mechanical Engineers, 1988, p. 361-367. refs

Solar dynamic power generating systems are being considered for the next generation of space platforms. NASA's Space Station, the most developed space platform concept, intends to add 50 kW of solar dynamic power generation capability to the initial 75 kW supplied by photovoltaics in the second phase of the program. To support the technical readiness of the solar dynamic organic Rankine cycle power system, a series of technical issues has been addressed through successful proof-of-concept demonstrations. The issues addressed and included in this presentation are: heat receiver development, thermal energy storage development, two-phase flow management, and working fluid thermal stability. Author

A89-29119#
SPACE STATION SOLAR CONCENTRATOR DEVELOPMENT
F. H. VALADE (Harris Corp., Government Aerospace Systems Div., Melbourne, FL) IN: Solar engineering - 1988; Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, CO, Apr. 10-14, 1988. New York, American Society of Mechanical Engineers, 1988, p. 369-374. refs

Solar dynamic concentrator technology for use aboard the Space Station is discussed. The design requirements are reviewed and the Space Station environment is described. The materials evaluation of candidate substrates and coatings is addressed, and the design details of a Space Station concentrator are examined. Developmental testing now being done is described. C.D.

A89-29122*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PHOTOVOLTAIC POWER MODULES FOR NASA'S MANNED SPACE STATION
C. A. TATRO (NASA, Lewis Research Center, Cleveland, OH) IN: Solar engineering - 1988; Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, CO, Apr. 10-14, 1988. New York, American Society of Mechanical Engineers, 1988, p. 489-497. Previously announced in STAR as N88-11745. refs

The capability and the safety of manned spacecraft are largely dependent upon reliable electric power systems. Two similar space power systems able to survive the low earth orbit environment, are being considered for NASA's Manned Space Station (SS), scheduled to begin operation in the mid 1990's. The Space Station Electric Power System (EPS) is composed of Photovoltaic (PV) Power Modules, Solar Dynamic (SD) Power Modules, and the Power Management and Distribution (PMAD) System. One EPS configuration will deliver 37.5 kW of PV based, utility grade, ac power to SS users. A second 75 kWe PV based EPS option is also being considered for SS deployment. The two EPS options utilize common modules and differ only in the total number of PV Power Modules used. Each PV Power Module supplies 18.75 kWe of ac power and incorporates its own energy storage and thermal control. The general requirements and the current preliminary design configuration of the Space Station PV Power Modules are examined. Author

A89-29123*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
LOW EARTH ORBIT ENVIRONMENTAL EFFECTS ON THE SPACE STATION PHOTOVOLTAIC POWER GENERATION SYSTEMS
H. K. NAHRA (NASA, Lewis Research Center, Cleveland, OH) IN: Solar engineering - 1988; Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, CO, Apr. 10-14, 1988. New York, American Society of Mechanical Engineers, 1988, p. 499-507. Previously announced in STAR as N88-12429. refs

A summary of the low earth orbital environment, its impact on the photovoltaic power systems of the Space Station and the solutions implemented to resolve the environmental concerns or issues are described. Low earth orbital environment (LEO) presents several concerns to the photovoltaic power systems of the Space Station. These concerns include atomic oxygen interaction with the polymeric substrate of the solar arrays, ionized environment effects on the array operating voltage, the effects of the meteoroids and debris impacts and penetration through the different layers of the solar cells and their circuits, and the high energy particle and radiation effects on the overall solar array performance. Potential solutions to some of the degrading environmental interactions that will provide the photovoltaic power system of the Space Station with the desired life are also summarized. Author

A89-30645
FUEL CELLS FOR EXTRATERRESTRIAL AND TERRESTRIAL APPLICATIONS
SUPRAMANIAM SRINIVASAN (Los Alamos National Laboratory, NM) Electrochemical Society, Journal (ISSN 0013-4651), vol. 136, Feb. 1989, p. 41C-48C. Research sponsored by DOE. refs

The principles of a fuel cell operation are examined, and the basic components of the electrochemical fuel-cell stack are described. Special attention is given to the technology and the materials used in the construction of five types of fuel cells, including the alkaline, the phosphoric-acid, the molten-carbonate, the solid-oxide, and the solid-polymer-electrolyte fuel cell systems. The prognosis for the economics and the applications of these fuel cell systems is considered. The lowest values of slopes of linear regions of cell potential current density plots (dE/di) are reported for the five types of fuel cells, and the schematic diagrams of these systems are presented. I.S.

N89-10106# Edgerton, Germeshausen and Grier, Inc., Idaho Falls, ID.
MULTIMEGAWATT POWER SOURCES FOR COMMERCIAL SPACE OPERATIONS
JOHN A. DEARIEN and JOHN S. MARTINELL 1988 8 p Presented at the 25th Space Congress, Cocoa Beach, Fla., 26 Apr. 1988
(Contract DE-AC07-76ID-01570)
(DE88-015119; EGG-M-88088; CONF-8804176-1) Avail: NTIS HC A02/MF A01

There is a great deal of interest in commercial operation in space today, but very little consideration of where the power to run such an operation is to come from. For any commercial operation in space, the power source, especially those involving kilowatts and megawatts of power, must be considered at the very onset of the venture. The Multimegawatt Space Reactor Program at the Idaho National Engineering Laboratory is working this problem in conjunction with the development of Strategic Defense Initiative needs. The same type of up-front power development program needs to be considered in all discussions associated with commercial development in space. A system developed for a commercial operation in space will most likely be a hybrid system utilizing both electrical and thermal energy. Even if the commercial process consists totally of high power thermal energy usage, there will be a certain amount of electricity required for controls, mass transport, environmental control (if manned), and communications. The optimum system will thus require a great deal of planning and coordination with the development of the commercial process. DOE

N89-10117*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE SOLAR DYNAMIC RADIATOR WITH A HISTORICAL PERSPECTIVE
K. L. MCLALLIN, M. L. FLEMING, F. W. HOEHN, and R. L. HOWERTON (Rockwell International Corp., Canoga Park, Calif.) Aug. 1988 12 p Presented at the 23rd Intersociety Energy Conversion Engineering Conference, Denver Colo., 31 Jul. - 5 Aug. 1988; sponsored in part by ASME, AIAA, ANS, SAE, IEEE, ACS, and AIChE
(NASA-TM-100972; E-4265; NAS 1.15:100972) Avail: NTIS HC A03/MF A01 CSCL 22B

A historical perspective on pumped-fluid loop space radiators provides a basis for the design of the Space Station Solar Dynamic (SD) power module radiator. SD power modules, capable of generating 25 kW (electrical) each, are planned for growth in Station power requirements. The Brayton cycle SD module configuration

incorporates a pumped-fluid loop radiator that must reject up to 99 kW (thermal). The thermal/hydraulic design conditions in combination with required radiator orientation and packaging envelope form a unique set of constraints as compared to previous pumped-fluid loop radiator systems. Nevertheless, past program successes have demonstrated a technology base that can be applied to the SD radiator development program to ensure a low risk, low cost system. Author

N89-10122*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PHOTOVOLTAICS FOR HIGH CAPACITY SPACE POWER SYSTEMS
DENNIS J. FLOOD Oct. 1988 16 p Presented at the 39th Annual Astronautical Congress of the International Astronautical Federation, Bangalore, India, 8-15 Oct. 1988
(NASA-TM-101341; E-4360; NAS 1.15:101341) Avail: NTIS HC A03/MF A01 CSCL 10B

The anticipated energy requirements of future space missions will grow by factors approaching 100 or more, particularly as a permanent manned presence is established in space. The advances that can be expected in solar array performance and lifetime, when coupled with advanced, high energy density storage batteries and/or fuel cells, will continue to make photovoltaic energy conversion a viable power generating option for the large systems of the future. The specific technologies required to satisfy any particular set of power requirements will vary from mission to mission. Nonetheless, in almost all cases the technology push will be toward lighter weight and higher efficiency, whether of solar arrays or storage devices. This paper will describe the content and direction of the current NASA program in space photovoltaic technology. The paper will also discuss projected system level capabilities of photovoltaic power systems in the context of some of the new mission opportunities under study by NASA, such as a manned lunar base, and a manned visit to Mars. Author

N89-10407*# Lockheed Missiles and Space Co., Sunnyvale, CA.
ADVANCED PLANAR ARRAY DEVELOPMENT FOR SPACE STATION Final Report
19 May 1987 68 p
(Contract NAS8-36419)
(NASA-CR-179372; NAS 1.26:179372) Avail: NTIS HC A04/MF A01 CSCL 10A

The objectives are to develop a process for manufacturing superstrate assemblies; demonstrate superstrate technology through fabrication and testing; develop and analyze a preliminary solar array wing design; and fabricate a wing segment based on the wing design. The task description, project flow diagram, and schedule are outlined. The progress to date is presented.
Author

N89-10933# Oak Ridge National Lab., TN.
PHASE CHANGE PROBLEM RELATED TO THERMAL ENERGY STORAGE IN THE MANNED SPACE STATION
D. G. WILSON, J. B. DRAKE, and R. E. FLANERY 1988 3 p Presented at the Institute for Mathematics and Its Applications Seminar, Minneapolis, Minn., 23 Feb. 1988
(Contract DE-AC05-84OR-21400)
(DE88-011390; CONF-880282-1) Avail: NTIS HC A02/MF A01

The system discussed consists of a solar collector lined with small metal canisters filled with a high temperature phase change material (PCM), lithium fluoride salt. The canisters are small enough to fit comfortably in the palm of one's hand and there are a hundred or more of them. A heat transfer fluid, an inert gas such as helium or neon, circulates through the pipes that pass through the metal canisters and carries heat away to turbines, generators, etc. The continual melting and refreezing of the PCM smears out the delivery of the solar energy to the transfer fluid, and hence, to the heat engines beyond. The motivation for using a PCM based thermal energy storage system is that a properly sized such system can store and deliver energy over a narrow temperature range near the melting point of the PCM, thus avoiding extreme temperature variations. DOE

N89-10941*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
THE STATE-OF-THE-ART OF DC POWER DISTRIBUTION SYSTEMS/COMPONENTS FOR SPACE APPLICATIONS
S. KRAUTHAMER Jul. 1988 92 p
(Contract NAS7-918)
(NASA-CR-182743; NAS 1.26:182743; JPL-PUBL-88-26) Avail: NTIS HC A05/MF A01 CSCL 10/2

This report is a survey of the state of the art of high voltage dc systems and components. This information can be used for consideration of an alternative secondary distribution (120 Vdc) system for the Space Station. All HVdc components have been prototyped or developed for terrestrial, aircraft, and spacecraft applications, and are applicable for general space application with appropriate modification and qualification. HVdc systems offer a safe, reliable, low mass, high efficiency and low EMI alternative for Space Station secondary distribution. Author

N89-11127*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
POWER QUALITY LOAD MANAGEMENT FOR LARGE SPACECRAFT ELECTRICAL POWER SYSTEMS
LOUIS F. LOLLAR Sep. 1988 23 p
(NASA-TM-100342; NAS 1.15:100342) Avail: NTIS HC A03/MF A01 CSCL 09/3

In December, 1986, a Center Director's Discretionary Fund (CDDF) proposal was granted to study power system control techniques in large space electrical power systems. Presented are the accomplishments in the area of power system control by power quality load management. In addition, information concerning the distortion problems in a 20 kHz ac power system is presented. Author

N89-11315*# Lockheed Missiles and Space Co., Sunnyvale, CA.
PV MODULES FOR GROUND TESTING Final Report
10 Sep. 1986 132 p
(Contract NAS3-24657)
(NASA-CR-179476; NAS 1.26:179476; LMSC/D973480) Avail: NTIS HC A07/MF A01 CSCL 10/1

The main objective was to design and build a minimum of three photovoltaic test panels for plasma interaction experiments. These experiments are intended to provide data on the interactions between high-voltage solar arrays and the space plasma environment. Data gathered will significantly contribute to the development of design criteria for the space station solar arrays. Electrical isolation between the solar cell strings and the module mounting plate is required for high-voltage bias. Author

N89-11505# Los Alamos National Lab., NM.
SPACE NUCLEAR SAFETY PROGRAM Progress Report, Jan. - Mar. 1987
T. C. GEORGE, comp. Jul. 1988 15 p
(Contract W-7405-ENG-36)
(DE88-015048; LA-11274-PR) Avail: NTIS HC A03/MF A01

This quarterly report describes studies related to the use of PuO2 (of Pu-238) in radioisotope power systems, which were carried out for the Office of Special Nuclear Projects of the U.S. Department of Energy by Los Alamos National Laboratory. Most of the studies discussed are ongoing; the results and conclusions described may change as the work progresses. DOE

N89-11508# Los Alamos National Lab., NM.
ANALYSIS OF SP-100 CRITICAL EXPERIMENTS
J. L. SAPIR, D. I. BRANDON, P. J. COLLINS, C. L. COWAN, C. A. PORTER, and S. V. ANDRE (Westinghouse Electric Corp., Madison, Pa.) 1988 15 p Presented at the International Reactor Physics Conference, Jackson Hole, Wyo., 18 Sep. 1988
(Contract W-7405-ENG-36)

(DE88-014429; LA-UR-88-2008; CONF-880911-14) Avail: NTIS HC A03/MF A01

In support of the SP-100 space nuclear power source program, preliminary critical benchmark experiments were performed at the ZPPR facility at ANL-W. These configurations are representative of small, fast-spectrum, BeO-reflected, liquid metal-cooled space reactor designs at a 300-kWe power level. Analyses were performed using MCNP (Monte Carlo) and TWODANT (discrete ordinates) transport codes to calculate system criticality, control worth, and power distribution. Both methods calculated eigenvalues within 0.5 percent of the experimental results. Internal-poison-rod worth was underpredicted and radial reflector worth was overpredicted by both codes by up to 20 percent. MCNP-calculated control drum worths were underestimated by approximately 8 percent. Good agreement with experimental values was observed for U-235 fission and for U-238 fission and capture rates with the best agreement occurring in the fuel region and slightly poorer predictions apparent near BeO moderator. DOE

N89-11802*# Arinc Research Corp., Annapolis, MD.
SPACE STATION ELECTRICAL POWER SYSTEM AVAILABILITY STUDY Final Contractor Report
SCOTT R. TURNQUIST and MARK A. TWOMBLY Nov. 1988 192 p
(Contract NASA ORDER C-31003-J)
(NASA-CR-182198; NAS 1.26:182198; ARINC-RP-5149-11-01-4744) Avail: NTIS HC A09/MF A01 CSCL 22/2

ARINC Research Corporation performed a preliminary reliability, and maintainability (RAM) anlaysis of the NASA space station Electric Power Station (EPS). The analysis was performed using the ARINC Research developed UNIRAM RAM assessment methodology and software program. The analysis was performed in two phases: EPS modeling and EPS RAM assessment. The EPS was modeled in four parts: the insolar power generation system, the eclipse power generation system, the power management and distribution system (both ring and radial power distribution control unit (PDCU) architectures), and the power distribution to the inner keel PDCUs. The EPS RAM assessment was conducted in five steps: the use of UNIRAM to perform baseline EPS model analyses and to determine the orbital replacement unit (ORU) criticalities; the determination of EPS sensitivity to on-orbit spared of ORUs and the provision of an indication of which ORUs may need to be spared on-orbit; the determination of EPS sensitivity to changes in ORU reliability; the determination of the expected annual number of ORU failures; and the integration of the power generator system model results with the distribution system model results to assess the full EPS. Conclusions were drawn and recommendations were made. Author

N89-12123*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
INP HOMOJUNCTION SOLAR CELL PERFORMANCE ON THE LIPS 3 FLIGHT EXPERIMENT
DAVID J. BRINKER, RUSSELL E. HART, JR., IRVING WEINBERG, and BRIAN S. SMITH 1988 11 p Presented at the 20th Photovoltaic Specialists Conference, Las Vegas, Nev., 26-30 Sep. 1988; sponsored by IEEE
(NASA-TM-101390; E-4454; NAS 1.15:101390) Avail: NTIS HC A03/MF A01 CSCL 10/1

Performance data for the NASA Lewis Research Center indium phosphide n+p homojunction solar cell module on the LIPS 3 Flight Experiment is presented. The objective of the experiment is to measure the performance of InP cells in the natural radiation environment of the 1100 km altitude, 60+ deg inclination orbit. Analysis of flight data indicates that the performance of the four cells throughout the first year is near expected values. No degradation in short-circuit current was seen, as was expected from radiation tolerance studies of similar cells. Details of the cell structure and flight module design are discussed. The results of the temperature dependency and radiation tolerance studies necessary for normalization and analysis of the data are included. Author

N89-12385# NUKEM G.m.b.H., Hanau (Germany, F.R.).
SAFETY ASPECTS OF NUCLEAR POWER SOURCES (NPS) FOR ELECTRICITY GENERATION IN SPACE Interim Summary Report, Nov. 1986 - Dec. 1987
H. J. WINGENDER and H. PIRK Feb. 1988 315 p Sponsored in cooperation with Technische Univ., Brunswick, Fed. Republic of Germany
(Contract BMFT-01-QV-8688-AK/PA2)
(FUE-87062; ETN-88-93229) Avail: NTIS HC A14/MF A01

Existing and future nuclear power sources (NPS) are described, and NPS are compared with other power sources in space. Statistics on NPS incidents are presented, and orbital lifetimes and reentry possibilities are predicted. The consequences and risks of NPS are assessed. ESA

N89-12399# TRW Space Technology Labs., Redondo Beach, CA. Applied Technology Div.
SPACE POWER MHD (MAGNETOHYDRODYNAMIC) SYSTEM Quarterly Technical Progress Report No. 3, 1 Nov. 1987 - 31 Jan. 1988
15 Mar. 1988 28 p
(Contract DE-AC22-87PC-79662)
(DE88-013085; DOE/PC-79662/T3; K535.88.RH-071) Avail: NTIS HC A03/MF A01

This progress report of the Space Power MHD System project presents the accomplishments during 1 November 1987 through 31 January 1988. The scope of work covered encompasses the definition of an MHD power system conceptual design and development plan (Task 1). Progress included the following: Subcontracts were issued to the MIT Plasma Fusion Center and the Westinghouse R and D Center. The performance of the 100 MW 500 sec. power system was optimized and the design concept finalized, including mass and energy balances. Mass and cost estimates were prepared. A design review was held at DOE/PETC. This also included the review of the technical issues definition and of the R and D Plan. Following the review, a final iteration on the conceptual design was initiated. Formulation of the R and D Plan was continued. Preparation of the Task 1 R and D Report was initiated. DOE

N89-13223# New Mexico Univ., Albuquerque. Student Branch of the American Nuclear Society.
NUCLEAR TECHNOLOGY FOR THE YEAR 2000
1987 112 p Proceedings of the 1987 Western Region American Nuclear Society Student Conference, Albuquerque, N. Mex., 19-21 Mar. 1987
(Contract DE-FG02-85ER-75172)
(DE88-005041; DOE/ER-75172/5; CONF-8703231-SUMMS)
Avail: NTIS HC A06/MF A01

Topics addressed include: space nuclear power; dosimetry and health physics; nuclear design and thermal hydraulics; nuclear diagnostics; fusion technology and plasma physics; and an overview of chernobyl.

N89-13225# New Mexico Univ., Albuquerque.
DOWN SCALE OF THE SP-100 CONCEPT FOR 5 KWE
BRAD EVANS and WILLIAM SCHUELER *In its* Nuclear Technology for the Year 2000 p 13-17 1987
Avail: NTIS HC A06/MF A01

The feasibility of using a SP-100 thermoelectric space reactor design as a 5 kWe power source, called the SP-5, was examined. The SP-100 is scaled down in size to give a high specific power by using the neutronics program FEMP2D. Possible future space missions may require a power source able to provide 5 kWe of power. There is an interest in using nuclear reactors in place of Radioactive Thermoelectric Generators (RTGs) for this low power demand because of the possibility of spreading toxic plutonium by the heat source if there was a launch accident. The SP-5 design will be compared to the RTGs on the basis of specific power, safety, and reliability. The reactor studied is the lithium cooled

SP-100. The core was reduced in size by using the neutronics program FEMP2D. A reactor was designed that is 35 cm high and 15.2 cm in radius. The shield mass is as high as 270 kg and to cool the reactor a radiator with a surface area of 5 square meters (50 kg) is required. This gives a total specific power of 8 We/kg. Author

N89-13227*# Oregon State Univ., Corvallis.
SPACE REACTOR ASSESSMENT AND VALIDATION STUDY Abstract Only
STEPHEN GEDEON and DENNIS MOREY *In* New Mexico Univ., Nuclear Technology for the Year 2000 p 24 1987
(Contract NAG3-752)
Avail: NTIS HC A06/MF A01

The present difficulties experienced by the United States in launching payloads into space has suggested a number of problems which are associated with the handling of hazardous materials in spacecraft. The question has arisen as to the safety of launching highly radioactive material such as plutonium-238, related to the possibility of its dispersion into the atmosphere during a launch vehicle explosion. An alternative is the use of a small nuclear reactor which is not started until it is in space and contains little or no radioactivity at launch. A first order assessment of six small reactor concepts with power levels up to 100 MWe was performed. Both the nuclear feasibility of these concepts to operate at their rated power levels between 7 and 10 years and the capability of these concepts to remain subcritical both before and during launch and also in the case of water immersion during a potential launch failure or abort were investigated. Author

N89-13829*# Eagle Engineering, Inc., Houston, TX.
CONCEPTUAL DESIGN OF A LUNAR BASE SOLAR POWER PLANT LUNAR BASE SYSTEMS STUDY TASK 3.3
14 Aug. 1988 60 p
(Contract NAS9-17878)
(NASA-CR-172086; NAS 1.26:172086; EEI-88-199) Avail: NTIS HC A04/MF A01 CSCL 10/2

The best available concepts for a 100 kW Solar Lunar Power Plant based on static and dynamic conversion concepts have been examined. The two concepts which emerged for direct comparison yielded a difference in delivered mass of 35 MT, the mass equivalent of 1.4 lander payloads, in favor of the static concept. The technologies considered for the various elements are either state-of-the-art or near-term. Two photovoltaic cell concepts should receive high priority for development: i.e., amorphous silicon and indium phosphide cells. The amorphous silicon, because it can be made so light weight and rugged; and the indium phosphide, because it shows very high efficiency potential and is reportedly not degraded by radiation. Also the amorphous silicon cells may be mounted on flexible backing that may roll up much like a carpet for compact storage, delivery, and ease of deployment at the base. The fuel cell and electrolysis cell technology is quite well along for lunar base applications, and because both the Shuttle and the forthcoming Space Station incorporate these devices, the status quo will be maintained. Early development of emerging improvements should be implemented so that essential life verification test programs may commence. F.M.R.

N89-14182*# Stirling Technology Co., Richland, WA.
THE 25 KWE SOLAR THERMAL STIRLING HYDRAULIC ENGINE SYSTEM: CONCEPTUAL DESIGN Final Report
MAURICE WHITE, GRANT EMIGH, JACK NOBLE, PETER RIGGLE, and TORVALD SORENSON Jan. 1988 242 p
(Contract DEN3-371; DE-AT04-85AL-33408)
(NASA-CR-180889; DOE/NASA/0371-1; NAS 1.26:180889; REPT-8803) Avail: NTIS HC A11/MF A01 CSCL 10/2

The conceptual design and analysis of a solar thermal free-piston Stirling hydraulic engine system designed to deliver 25 kWe when coupled to a 11 meter test bed concentrator is documented. A manufacturing cost assessment for 10,000 units per year was made. The design meets all program objectives including a 60,000 hr design life, dynamic balancing, fully automated control, more than 33.3 percent overall system efficiency, properly conditioned power, maximum utilization of annualized insolation, and projected production costs. The system incorporates a simple, rugged, reliable pool boiler reflux heat pipe to transfer heat from the solar receiver to the Stirling engine. The free-piston engine produces high pressure hydraulic flow which powers a commercial hydraulic motor that, in turn, drives a commercial rotary induction generator. The Stirling hydraulic engine uses hermetic bellows seals to separate helium working gas from hydraulic fluid which provides hydrodynamic lubrication to all moving parts. Maximum utilization of highly refined, field proven commercial components for electric power generation minimizes development cost and risk. Author

N89-14247*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
POWER SYSTEMS FACILITY
Jan. 1989 27 p Original contains color illustrations
(NASA-TM-101447; E-4553; NAS 1.15:101447) Avail: NTIS HC A03/MF A01 CSCL 14/2

In 1984, the President directed NASA to undertake the development of Space Station Freedom, the next step in a broad-based U.S. civil space program to develop space-flight capabilities and to exploit space for scientific, technological, and commercial purposes. Under that direction, NASA awarded contracts in 1985 for concept definition and preliminary design studies. Those studies have been completed and the Space Station Freedom Program is now in the final design and development phase, leading to a permanently manned space station that will be operational in the mid-1990's. Here at the Lewis Research Center, with Rocketdyne, we are developing and building the S.S. Freedom electric power system (EPS) hardware and software. A major portion of the EPS will be tested at Lewis. The Power Systems Facility was specifically designed for testing the EPS and uses the latest in testing equipment. Author

N89-15164*# Rockwell International Corp., Canoga Park, CA. Rocketdyne Div.
SPACE STATION WP-04 POWER SYSTEM PRELIMINARY ANALYSIS AND DESIGN DOCUMENT, VOLUME 3
19 Dec. 1986 372 p
(Contract NAS3-24666)
(NASA-CR-179587-VOL-3; NAS 1.26:179587-VOL-3; RI/RD85-320-2-VOL-3) Avail: NTIS HC A16/MF A01 CSCL 10/2

Rocketdyne plans to generate a system level specification for the Space Station Electric Power System (EPS) in order to facilitate the usage, accountability, and tracking of overall system level requirements. The origins and status of the verification planning effort are traced and an overview of the Space Station program interactions are provided. The work package level interfaces between the EPS and the other Space Station work packages are outlined. A trade study was performed to determine the peaking split between PV and SD, and specifically to compare the inherent total peaking capability with proportionally shared peaking. In order to determine EPS cost drivers for the previous submittal of DRO2, the life cycle cost (LCC) model was run to identify the more significant costs and the factors contributing to them. B.G.

N89-15171*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ISSUES AND OPPORTUNITIES IN SPACE PHOTOVOLTAICS
ROBERT W. FRANCIS, W. A. SOMERVILLE (Aerospace Corp., El Segundo, CA.), and DENNIS J. FLOOD 1988 14 p Presented at the 20th Photovoltaic Specialists Conference, Las Vegas, NV, 26-30 Sep. 1988; sponsored by the Institute of Electrical and Electronics Engineers
(NASA-TM-101425; E-4526; NAS 1.15:101425) Avail: NTIS HC A03/MF A01 CSCL 10/2

Space power sources are becoming a central focus for determining man's potential and schedule for exploring and utilizing the benefits of space. The ability to search, probe, survey, and communicate throughout the universe will depend on providing adequate power to the instruments to do these jobs. Power requirements for space platforms are increasing and will continue

to increase into the 21st century. Photovoltaics have been a dependable power source for space for the last 30 years and have served as the primary source of power on virtually all DOD and NASA satellites. The performance of silicon (Si) solar cells has increased from 10 percent air mass zero (AM0) solar energy conversion efficiency in the early 60's to almost 15 percent on today's spacecraft. Some technologists even think that the potential for solar photovoltaics has reached a plateau. However, present and near-future Air Force and NASA requirements show needs that, if the problems are looked upon as opportunities, can elevate the photovoltaic power source scientist and array structure engineer into the next technological photovoltaic growth curve. Author

N89-15379* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
FLUIDIC MOMENTUM CONTROLLER Patent
RONALD S. MAYNARD, inventor (to NASA) 11 Oct. 1988 11 p Continuation of US-Patent-Appl-SN-779742, filed 24 Sep. 1985, abandoned
(NASA-CASE-MSC-20906-2; US-PATENT-4,776,541; US-PATENT-APPL-SN-021569; US-PATENT-CLASS-244-165; US-PATENT-CLASS-74-572; US-PATENT-CLASS-244-164)
Avail: US Patent and Trademark Office CSCL 14/2

Large angular control moments and torques are developed by controllably circulating a relatively small mass of liquid through small diameter pipes describing a large diameter loop. The loop, by generating and storing angular momentum, can thereby provide efficient cancellation of periodic, non-accumulating, externally induced rotational disturbances. The loop is preferably located on or near the periphery of a structure which is to be stabilized.
Official Gazette of the U.S. Patent and Trademark Office

N89-15579*# Case Western Reserve Univ., Cleveland, OH. Dept. of Computer Engineering and Science.
A CLIPS PROTOTYPE FOR AUTONOMOUS POWER SYSTEM CONTROL
JAMES M. VEZINA and LEON STERLING *In* NASA, Marshall Space Flight Center, Fourth Conference on Artificial Intelligence for Space Applications p 211-220 Oct. 1988
Avail: NTIS HC A21/MF A01 CSCL 21/8

The model of the system assumes a constant power source and loads (experiments) whose power demands exceed the supply. Experiments are described by their name, power consumption, time for a complete run, present status and the state of the load. The power consumption of each load is set at a constant level but can be dynamically modified by the operator. The status specifies if the experiment is running, paused, completed or failed. The state compensates for the lack of actual feedback sensor data, by signifying the stability of the load. Experiments are scheduled to keep as many running as possible with the current system limitations. A graphics oriented user interface is embedded into the rule-based system to enable an operator to easily experiment with the system. Author

N89-15802*# Alabama Univ., Huntsville. Dept. of Electrical and Computer Engineering.
ARCING AND DISCHARGES IN HIGH-VOLTAGE SUBSYSTEMS OF SPACE STATION
N. SINGH *In* NASA, Marshall Space Flight Center, Space Station Induced Monitoring p 77-81 Nov. 1988
Avail: NTIS HC A05/MF A01 CSCL 22/2

Arcing and other types of electrical discharges are likely to occur in high-voltage subsystems of the Space Station. Results from ground and space experiments on the arcing of solar cell arrays are briefly reviewed, showing that the arcing occurs when the conducting interconnects in the arrays are at negative potential above a threshold, which decreases with the increasing plasma density. Furthermore, above the threshold voltages the arcing rate increases with the plasma density. At the expected operating voltages (approximately 200 V) in the solar array for the space station, arcing is expected to occur even in the ambient ionospheric plasma. If the ionization of the contaminants increases the plasma density near the high-voltage systems, the adverse effects of arcing on the solar arrays and the space station are likely to be enhanced, In addition to arcing other discharge processes are likely to occur in high-voltage subsystems. For example, Paschen discharge is likely to occur when the neutral density N sub n greater that 10 to the 12th cu cm, the corresponding neutral pressure P greater than 3 x 10 to the -5 Torr. Author

N89-16224*# Sanders Associates, Inc., Nashua, NH.
ADVANCED HEAT RECEIVER CONCEPTUAL DESIGN STUDY Final Report, May 1986 - Jul. 1988
JAMES KESSELI, ROGER SAUNDERS, and GARY BATCHELDER Oct. 1988 238 p
(Contract NAS3-24858)
(NASA-CR-182177; NAS 1.26:182177) Avail: NTIS HC A11/MF A01 CSCL 10/1

Solar Dynamic space power systems are candidate electrical power generating systems for future NASA missions. One of the key components of the solar dynamic power system is the solar receiver/thermal energy storage (TES) subsystem. Receiver development was conducted by NASA in the late 1960's and since then a very limited amount of work has been done in this area. Consequently the state of the art (SOA) receivers designed for the IOC space station are large and massive. The objective of the Advanced Heat Receiver Conceptual Design Study is to conceive and analyze advanced high temperature solar dynamic Brayton and Stirling receivers. The goal is to generate innovative receiver concepts that are half of the mass, smaller, and more efficient than the SOA. It is also necessary that these innovative receivers offer ease of manufacturing, less structural complexity and fewer thermal stress problems. Advanced Brayton and Stirling receiver storage units are proposed and analyzed in this study which can potentially meet these goals. Author

N89-16917*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NASA PHOTOVOLTAIC RESEARCH AND TECHNOLOGY
DENNIS J. FLOOD Dec. 1988 12 p Prepared for the Annual Meeting of the American Institute of Chemical Engineers, Washington, DC, 28 Nov. - 2 Dec. 1988
(NASA-TM-101422; E-4522; NAS 1.15:101422) Avail: NTIS HC A03/MF A01 CSCL 10/2

NASA photovoltaic R and D efforts address future Agency space mission needs through a comprehensive, integrated program. Activities range from fundamental studies of materials and devices to technology demonstrations of prototype hardware. The program aims to develop and apply an improved understanding of photovoltaic energy conversion devices and systems that will increase the performance, reduce the mass, and extend the lifetime of photovoltaic arrays for use in space. To that end, there are efforts aimed at improving cell efficiency, reducing the effects of space particulate radiation damage (primarily electrons and protons), developing ultralightweight cells, and developing advanced ray component technology for high efficiency concentrator arrays and high performance, ultralightweight arrays. Current goals that have been quantified for the program are to develop cell and array technology capable of achieving 300 watts/kg for future missions for which mass is a critical factor, or 300 watts/sq m for future missions for which array size is a major driver (i.e., Space Station). A third important goal is to develop cell and array technology which will survive the GEO space radiation environment for at least 10 years. Author

N89-17348# Naval Postgraduate School, Monterey, CA.
A MICROPROCESSOR-BASED, SOLAR CELL PARAMETER MEASUREMENT SYSTEM M.S. Thesis
ROBERT R. OXBORROW Jun. 1988 89 p
(AD-A200227) Avail: NTIS HC A05/MF A01 CSCL 10/2

The effects of the space environment on solar cells has, to date, been largely modeled and approximated in the design of solar arrays. Restrictions such as weight and cost have precluded direct analysis of the long term effects of radiation in space. At the Naval Postgraduate School (NPS), a simple circuit has been devised which facilitates in situ data collection and analysis of

these effects. The circuit includes an op-amp and a high beta transistor for cell voltage biasing. When coupled to a microprocessor-based controller system, this circuit has the capability to measure and store data pertaining to solar cell performance I-V curves. The complete system consists of an NSC 800 microprocessor, D/A and A/D components, analog multiplexers and demultiplexers, biasing transistors and op-amps. This design provides a compact, low power, accurate method for I-V measurement and data storage. Such a system may be used to observe and monitor an array of test cells and their performance degradation in both the space environment and terrestrial applications. GRA

N89-17941*# Space Power, Inc., San Jose, CA.
MEGAWATT CLASS NUCLEAR SPACE POWER SYSTEMS (MCNSPS) CONCEPTUAL DESIGN AND EVALUATION REPORT. VOLUME 1: OBJECTIVES, SUMMARY RESULTS AND INTRODUCTION Final Report
J. R. WETCH et al. Sep. 1988 40 p Sponsored in part by DOD, Washington, DC and DOE, Washington, DC
(Contract NAS3-23867)
(NASA-CR-179614-VOL-1; NAS 1.26:179614-VOL-1; SPI-25-1)
Avail: NTIS HC A03/MF A01 CSCL 10/2

The objective was to determine which reactor, conversion, and radiator technologies would best fulfill future Megawatt Class Nuclear Space Power System Requirements. Specifically, the requirement was 10 megawatts for 5 years of full power operation and 10 years systems life on orbit. A variety of liquid metal and gas cooled reactors, static and dynamic conversion systems, and passive and dynamic radiators were considered. Four concepts were selected for more detailed study. The concepts are: a gas cooled reactor with closed cycle Brayton turbine-alternator conversion with heat pipe and pumped tube-fin heat rejection; a lithium cooled reactor with a free piston Stirling engine-linear alternator and a pumped tube-fin radiator; a lithium cooled reactor with potassium Rankine turbine-alternator and heat pipe radiator; and a lithium cooled incore thermionic static conversion reactor with a heat pipe radiator. The systems recommended for further development to meet a 10 megawatt long life requirement are the lithium cooled reactor with the K-Rankine conversion and heat pipe radiator, and the lithium cooled incore thermionic reactor with heat pipe radiator. Author

N89-18177# Department of Energy, Washington, DC. Office of Nuclear Energy.
IMPORTANT TECHNOLOGY CONSIDERATIONS FOR SPACE NUCLEAR POWER SYSTEMS
JOHN P. KUSPA, EARL J. WAHLQUIST, and DENNIS A. BITZ Mar. 1988 28 p
(DE89-004005; DOE/NE-0093) Avail: NTIS HC A03/MF A01

This paper discusses the technology considerations that guide the development of space nuclear power sources (NPS) by the Department of Energy (DOE) to meet a wide variety of applications. The Department and its predecessor agencies have been developing NPS since the 1950s and producing NPS for spacecraft for the National Aeronautics and Space Administration (NASA) and the Department of Defense (DOD) since the early 1960s. No one nuclear power type, isotope or reactor, will suffice over the entire range of mission power required. Nor is one type of power conversion system, be it static or dynamic, the optimum choice of all space nuclear power system applications. There is a need for DOE, in partnership with its users, NASA and DOD, to develop a variety of types of space nuclear power sources - isotope-static, isotope-dynamic, reactor-static, and reactor-dynamic - to meet mission requirements well into the next century. DOE

N89-18178# Department of Energy, Washington, DC.
ENVIRONMENTAL ASSESSMENT OF SP-100 GROUND ENGINEERING SYSTEM TEST SITE: HANFORD SITE, RICHLAND, WASHINGTON
Dec. 1988 279 p
(DE89-004400; DOE/EA-0318) Avail: NTIS HC A13/MF A01

The US Department of Energy (DOE) proposes to modify an existing reactor containment building (decommissioned Plutonium Recycle Test Reactor (PRTR) 309 Building) to provide ground test capability for the prototype SP-100 reactor. The 309 Building (Figure 1.1) is located in the 300 Area on the Hanford Site in Washington State. The National Environmental Policy Act (NEPA) requires that Federal agencies assess the potential impacts that their actions may have on the environment. This Environmental Assessment describes the consideration given to environmental impacts during reactor concept and test site selection, examines the environmental effects of the DOE proposal to ground test the nuclear subsystem, describes alternatives to the proposed action, and examines radiological risks of potential SP-100 use in space. DOE

N89-18520# Naval Postgraduate School, Monterey, CA.
A PROTOTYPE FAULT DIAGNOSIS SYSTEM FOR NASA SPACE STATION POWER MANAGEMENT AND CONTROL M.S. Thesis
GINA L. HESTER Sep. 1988 145 p
(AD-A202032) Avail: NTIS HC A07/MF A01 CSCL 22/5

The Power Management and Distribution System (PMAD) prototype utilizes a computer graphics interface with a computer expert system running transparent to the user and a computer communications interface that links the two together, all enabling the diagnosis of PMAD system faults. The prototype design is based on the concept that an astronaut on a space station will instruct an expert system through a graphic interface to run a system or component check on the PMAD system. The graphics interface determines which type of evaluations was requested and sends that information through the communications interface to the expert system. The expert system receives the information and, based on the type of evaluation requested, executes the appropriate rules in the knowledge base and sends the resulting status back to the graphics interface and the astronaut. The PMAD System Prototype serves as a proposed training tool for NASA to use in the training of new personnel who will be designing and developing the NASA Space station expert systems. GRA

N89-18967*# Space Power, Inc., San Jose, CA.
MEGAWATT CLASS NUCLEAR SPACE POWER SYSTEMS (MCNSPS) CONCEPTUAL DESIGN AND EVALUATION REPORT. VOLUME 4: CONCEPTS SELECTION, CONCEPTUAL DESIGNS, RECOMMENDATIONS
J. R. WETCH et al. Sep. 1988 111 p
(Contract NAS3-23867)
(NASA-CR-179614-VOL-4; NAS 1.26:179614-VOL-4;
SPI-25-1-VOL-4) Avail: NTIS HC A06/MF A01 CSCL 10/2

A study was conducted by NASA Lewis Research Center for the Triagency SP-100 program office. The objective was to determine which reactor, conversion and radiator technologies would best fulfill future Megawatt Class Nuclear Space Power System Requirements. The requirement was 10 megawatts for 5 years of full power operation and 10 years system life on orbit. A variety of liquid metal and gas cooled reactors, static and dynamic conversion systems, and passive and dynamic radiators were considered. Four concepts were selected for more detailed study: (1) a gas cooled reactor with closed cycle Brayton turbine-alternator conversion with heatpipe and pumped tube fin rejection, (2) a Lithium cooled reactor with a free piston Stirling engine-linear alternator and a pumped tube-fin radiator,(3) a Lithium cooled reactor with a Potassium Rankine turbine-alternator and heat pipe radiator, and (4) a Lithium cooled incore thermionic static conversion reactor with a heat pipe radiator. The systems recommended for further development to meet a 10 megawatt long life requirement are the Lithium cooled reactor with the K-Rankine conversion and heat pipe radiator, and the Lithium cooled incore thermionic reactor with heat pipe radiator. Author

N89-19822*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
AUTOMATION OF THE SPACE STATION CORE MODULE POWER MANAGEMENT AND DISTRIBUTION SYSTEM
DAVID J. WEEKS *In* NASA. Lyndon B. Johnson Space Center,

2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 25-29 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 22/2

Under the Advanced Development Program for Space Station, Marshall Space Flight Center has been developing advanced automation applications for the Power Management and Distribution (PMAD) system inside the Space Station modules for the past three years. The Space Station Module Power Management and Distribution System (SSM/PMAD) test bed features three artificial intelligence (AI) systems coupled with conventional automation software functioning in an autonomous or closed-loop fashion. The AI systems in the test bed include a baseline scheduler/dynamic rescheduler (LES), a load shedding management system (LPLMS), and a fault recovery and management expert system (FRAMES). This test bed will be part of the NASA Systems Autonomy Demonstration for 1990 featuring cooperating expert systems in various Space Station subsystem test beds. It is concluded that advanced automation technology involving AI approaches is sufficiently mature to begin applying the technology to current and planned spacecraft applications including the Space Station. Author

N89-19825*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
AUTOMATIC DETECTION OF ELECTRIC POWER TROUBLES (ADEPT)
CAROLINE WANG, HUGH ZEANAH, AUDIE ANDERSON, CLINT PATRICK, MIKE BRADY, and DONNIE FORD (Alabama A & M Univ., Huntsville.) *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 47-50 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 09/3

Automatic Detection of Electric Power Troubles (A DEPT) is an expert system that integrates knowledge from three different suppliers to offer an advanced fault-detection system. It is designed for two modes of operation: real time fault isolation and simulated modeling. Real time fault isolation of components is accomplished on a power system breadboard through the Fault Isolation Expert System (FIES II) interface with a rule system developed in-house. Faults are quickly detected and displayed and the rules and chain of reasoning optionally provided on a laser printer. This system consists of a simulated space station power module using direct-current power supplies for solar arrays on three power buses. For tests of the system's ablilty to locate faults inserted via switches, loads are configured by an INTEL microcomputer and the Symbolics artificial intelligence development system. As these loads are resistive in nature, Ohm's Law is used as the basis for rules by which faults are located. The three-bus system can correct faults automatically where there is a surplus of power available on any of the three buses. Techniques developed and used can be applied readily to other control systems requiring rapid intelligent decisions. Simulated modeling, used for theoretical studies, is implemented using a modified version of Kennedy Space Center's KATE (Knowledge-Based Automatic Test Equipment), FIES II windowing, and an ADEPT knowledge base. Author

08

ELECTRONICS

Includes descriptions of analytical techniques, analyses, systems, and requirements for internal and external communications, electronics, sensors for position and systems monitoring and antennas.

A89-10265* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
THREE BEAM-COMBINING SCHEMES IN A COLOR PROJECTION DISPLAY
MARIJA S. SCHOLL (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Current developments in optical engineering II; Proceedings of the Meeting, San Diego, CA, Aug. 18-21, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 196-205. refs

Several beam-combining schemes for on-axis and off-axis optical system layout are presented. The on-axis approaches include two crossed plates with dichroic coatings placed at 90 deg, with respect to each other, and a pentaprism arrangement. The off-axis layout of the cathode ray tubes requires that the images be combined at the display screen. These image-combining approaches are compared for the standard television rates of 525 lines and the high-resolution television at 1200/2000 lines under development in Japan. It is concluded that, for the high-performance, high-color fidelity, and high-resolution projection systems, which are expected to fit into a small volume of space such as a Space Station display or a cockpit panoramic display, a folded configuration with either crossed plates or pentaprism plates will result in an optimum color display. Author

A89-14136
EARTH-TO-SATELLITE MICROWAVE BEAMS - INNOVATIVE APPROACH TO SPACE POWER
M. I. HOFFERT, G. MILLER, B. HEILWEIL, W. ZIEGLER, and M. KADIRAMANGALAM (New York University, NY) IN: Microwave and particle beam sources and propagation; Proceedings of the Meeting, Los Angeles, CA, Jan. 13-15, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 148-169. SDIO-sponsored research. refs
(Contract DAAL02-86-K-0116)

A new space power concept incorporating earth-to-satellite microwave power beams coupled to onboard-regeneration electrochemical energy storage is proposed for energizing defensive satellite constellations. The system addresses housekeeping, orbital maneuvering, and burst-mode power requirements, and offers an attractive alternative to the nuclear and solar space power systems currently envisioned for this application. Component and overall system considerations of this scheme are discussed and compared with alternatives. Outstanding research problems are defined and preliminary analyses pertaining to orbital mechanics and satellite ground tracks, accessibility of orbits to microwave beams, transmission efficiencies, electronic and mechanical designs for the transmitter and rectenna, regenerative fuel cell energy storage, power conditioning, and thermal management are addressed. C.D.

A89-15354* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
AN AUTOMATED DYNAMIC LOAD FOR POWER SYSTEM DEVELOPMENT
NORMA DUGAL WHITEHEAD and ROBERT E. KAPUSTKA (NASA, Marshall Space Flight Center, Huntsville, AL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 437-440.

This paper describes a dynamic load which is computer-controlled and has an increased bandwidth of more than 10 times that commercially available at the time the development of the project began. The load is 3 kW with a bandwidth of 35 kHz. The hardware and software are described, and the control circuitry is shown. C.D.

A89-15702
TAILORING HEMTS FOR LOW-NOISE AMPLIFIER DESIGNS
A. A. JABRA, P. M. SMITH, P. C. CHAO (GE Electronics Laboratory, Syracuse, NY), and M. BACCARINI (General Electric Co., Government Communications System Div., Camden, NJ) Microwaves & RF (ISSN 0745-2993), vol. 27, Oct. 1988, p. 99, 100, 102.

A Ku-band low-noise amplifier (LNA) for use in a multiple-access communication network such as that required by the Space Station is described. The unit uses high-electron-mobility transistors (HEMTs) to achieve 1.5-dB noise figure and 30-dB gain over its

13.4-13.8 GHz design bandwidth. HEMT technology is discussed as well as Ku-band amplifier design and amplifier performance.
K.K.

A89-15793
FREE-SPACE LASER COMMUNICATION TECHNOLOGIES; PROCEEDINGS OF THE MEETING, LOS ANGELES, CA, JAN. 11, 12, 1988
GERHARD A. KOEPF, ED. (Ball Corp., Ball Aerospace Systems Div., Boulder, CO) and DAVID L. BEGLEY, ED. (McDonnell Douglas Astronautics Co., Saint Louis, MO) Meeting sponsored by SPIE. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Volume 885), 1988, 216 p. For individual items see A89-15794 to A89-15818.
(SPIE-885)

The present conference discusses topics in free-space laser communications, laser link characteristics, satellite laser communication systems, optoelectronic components for laser communications, and space laser subsystem technologies. Attention is given to Space Station-based deep-space communication experiments, the application of intersatellite links to operational satellite systems, high-power 0.87 micron channel substrate planar lasers for spaceborne communications, a ground experiment using a CO2 laser transceiver for free-space communications, studies of laser ranging to the TOPEX satellite, diffraction-limited tracking for space communications, and the compact implementation of a real-time, acoustooptic SAR processor. O.C.

A89-15796* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SPACE STATION-BASED DEEP-SPACE OPTICAL COMMUNICATION EXPERIMENTS
CHIEN-CHUNG CHEN and JON A. SCHWARTZ (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Free-space laser communication technologies; Proceedings of the Meeting, Los Angeles, CA, Jan. 11, 12, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 18-23. refs

A series of three experiments proposed for advanced optical deep-space communications is described. These proposed experiments would be carried out aboard the Space Station to test and evaluate the capability of optical instruments to conduct data communication and spacecraft navigation for deep-space missions. Techniques for effective data communication, precision spacecraft ranging, and accurate angular measurements will be developed and evaluated in a spaceborne environment. Author

A89-17651#
INFLATABLE, SPACE-RIGIDIZED ANTENNA REFLECTORS - FLIGHT EXPERIMENT DEFINITION
M. C. BERNASCONI (Contraves AG, Zurich, Switzerland) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 7 p. refs
(Contract ESA-6244/85/NL/PB)
(IAF PAPER 88-049)

Large structures are of growing importance for space operations. In the near-term advanced expandable structures will see an increased use. The technology of inflatable, chemically-rigidized structures (ISRS) has been studied to enable realization of such large expandables. After a review of the development approach, the concept of a technological flight experiment is introduced and its rationale discussed. The paper presents the experiment philosophy, its concept, instrumentation and initial design. The expected behavior of the experimental object is summarized, to review its impact on the instrumentation. Author

A89-17826#
INTER ORBIT COMMUNICATIONS (IOC)
J. P. POULIQUEN and R. TRIBES (CNES, Toulouse, France) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 7 p.
(IAF PAPER 88-446)

The Inter Orbit Communication (IOC) program, an ESA experimental payload aboard the EURECA platform which is to manage a 20/30 GHz bidirectional link with the ground, is discussed. The IOC objective is reviewed and the system is described, including the Olympus relay to the ground. The payload and antenna pointing are described in detail. The IOC development and exploitation planning schedule is shown. C.D.

A89-18140#
SELECTION OF A TRANSFER FRAME FORMAT FOR SPACE STATION COMMUNICATIONS
RICHARD A. RADECKI (McDonnell Douglas Astronautics Co., Huntington Beach, CA) IN: AIAA/IEEE Digital Avionics Systems Conference, 8th, San Jose, CA, Oct. 17-20, 1988, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 603-606. refs
(AIAA PAPER 88-3980)

International use of space-to-ground and command telemetry standards will enhance international cooperation and minimize new hardware and software systems for future space experiments and exploration. An international committee led by NASA has been reviewing requirements for such standards and has drafted recommendations. This paper examines the Space Station requirements and discusses options for isochronous data handling, grade of service control, circuit establishment, and link control signaling that fit within the international recommendations.
Author

A89-18170*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
AN INNOVATIVE APPROACH TO SUPPLYING AN ENVIRONMENT FOR THE INTEGRATION AND TEST OF THE SPACE STATION DISTRIBUTED AVIONICS SYSTEMS
THOMAS BARRY (NASA, Johnson Space Center, Houston, TX), TERRANCE SCHEFFER (McDonnell Douglas Astronautics Co., Saint Louis, MO), and L. R. SMALL (IBM, Armonk, NY) IN: AIAA/IEEE Digital Avionics Systems Conference, 8th, San Jose, CA, Oct. 17-20, 1988, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 788-791.
(AIAA PAPER 88-3978)

This paper describes an innovative approach to supplying an environment for the integration and testing of the Space Station distributed avionics systems. The environment's relationship to the process flow of the Space Station verification from systems development to on-orbit verification is presented. This paper also describes the uses of the environment's hardware implementation called Data Management System (DMS) kits. The way in which this environment allows system developers to independently verify their system's performance, fault detection, and recovery capability is explained. Author

A89-20197* Drexel Univ., Philadelphia, PA.
OPTICALLY RECONFIGURED ACTIVE PHASED ARRAY ANTENNAS
A. S. DARYOUSH and B. CHOE (Drexel University, Philadelphia, PA) Microwave and Optical Technology Letters (ISSN 0895-2477), vol. 1, Nov. 1988, p. 344-348. Research supported by Du Pont de Nemours and Co., AEL, and NASA. refs

Future generations of phased array antennas for space-based and airborne platforms are designed based on a large number of active T/R modules. The constructed radiating beam is degraded in the event of modules failure. Simulation results indicate that the control of frequency, interelement spacing, and the individual radiating element pattern alongside the more conventional technique of amplitude and phase can be used to reconfigure the desired radiating beam in the event of the active T/R module failure. Author

A89-22436* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
THE SPACE RADIATION ENVIRONMENT FOR ELECTRONICS
E. G. STASSINOPOULOS (NASA, Goddard Space Flight Center,

Greenbelt, MD) and JAMES P. RAYMOND (Mission Research Corp., San Diego, CA) IEEE, Proceedings (ISSN 0018-9219), vol. 76, Nov. 1988, p. 1423-1442. refs

The earth's space radiation environment is described in terms of charged particles as relevant to effects on spacecraft electronics. The nature and magnitude of the trapped and transiting environments are described in terms of spatial distribution and temporal variation. The internal radiation environment of the spacecraft is described in terms of shielding the high-energy particles of the free-field environment. Exposure levels are presented in terms of ionizing radiation dose and particle fluence for comparison to electronic component susceptibility. I.E.

A89-24477
OPTICAL SENSORS FOR RELATIVE TRAJECTORY CONTROL
A. S. MENARDI (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IN: Automatic control; Proceedings of the Tenth Triennial World Congress of IFAC, Munich, Federal Republic of Germany, July 27-31, 1987. Volume 6. Oxford, England and Elmsford, NY, Pergamon Press, 1988, p. 1-4. refs

The current development status of optical sensors for spacecraft applications is surveyed, with a focus on sensors used to determine spacecraft orientation relative to celestial objects. Topics addressed include optoelectronic detectors for IR and visible sensors, sun and earth sensors, star trackers and mappers, and planetary and cometary sensors. Particular attention is given to sensors for automated rendezvous and docking operations and for space robotics. T.K.

A89-25433#
DYNAMICS OF THE ORBITER BASED WISP EXPERIMENT
V. J. MODI and A. M. IBRAHIM (British Columbia, University, Vancouver, Canada) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p.
(Contract NSERC-A-2181)
(AIAA PAPER 89-0540)

A methodology for formulating equations of motion applicable to a large class of systems with interconnected flexible deployable members is briefly outlined. Effectiveness of the formulation is illustrated through its application to a problem of contemporary interest, the WISP (Waves In Space Plasma) dipole antenna aboard the Space Shuttle. The parametric study suggests that under critical combinations of parameters, the system is susceptible to instability. The information is fundamental to the planning of the WISP experiment. Author

A89-25488#
OBSERVATION OF SURFACE CHARGING ON ENGINEERING TEST SATELLITE V OF JAPAN
HIRONOBU NISHIMOTO (National Space Development Agency of Japan, Tsukuba), HARUHISA FUJII (Mitsubishi Electric Corp., Manufacturing Development Laboratory, Amagasaki, Japan), and TOSHIO ABE (Mitsubishi Electric Corp., Kamakura, Japan) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(AIAA PAPER 89-0613)

A potential monitor (POM) was developed and was installed on geostationary Engineering Test Satellite V of Japan launched on August 27, 1987. The POM can measure the surface potentials of insulating material samples which get charged in the space environment. Three kinds of thermal control materials were used as the samples. The following observational results were obtained: (1) the charging potentials increased negatively in the shadow of antenna or shunt of solar array paddle, (2) the potentials gradually increased for one year, and (3) the potentials changed periodically with the temperature of the sensing part of the POM. Author

A89-26968* Cubic Corp., San Diego, CA.
TARGET ACQUISITION AND TRACK IN THE LASER DOCKING SENSOR
TED J. CLOWES (Cubic Corp., Defense Systems Div., San Diego,CA) and RICHARD F. SCHUMA (Cubic Corp., Electro-Optical Div., Teterboro, NJ) IN: Sensor fusion; Proceedings of the Meeting, Orlando, FL, Apr. 4-6, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 143-148.
(Contract NAS9-17846)

A sensor designed to aid in the docking of spacecraft is under development for NASA. This sensor uses three lasers to track the prospective target and to determine the required parameters necessary to calculate the ideal approach maneuver. The system combines the inputs from several sensors, including polarization, continuous tone DME, and a CID to achieve the desired results. Author

A89-29928
MICROWAVE POWER BEAMING FROM EARTH-TO-SPACE
WALT S. GREGORWICH (Lockheed Research Laboratories, Palo Alto, CA) IN: 1988 IEEE Aerospace Applications Conference, Park City, UT, Feb. 7-12, 1988, Digest. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, 9 p. refs

The author presents an overview of the potential and limitations of microwave power transfer. In addition, state-of-the-art technology is reviewed as well as required hardware to implement such a system. Tradeoffs among frequency selection, atmospheric effects, orbital geometry and energy storage are discussed. Present hardware capabilities of ground station antennas, microwave power sources, and spacecraft receiving antennas such as large unfurlable and space erectable dishes, deployable rectennas, and tethered systems are also reviewed. It is concluded that on the basis of present technology, the efficient transfer of microwave power from earth to a low-orbiting satellite is feasible. I.E.

A89-30809#
ACTIVE ACCURACY ADJUSTMENT OF REFLECTORS THROUGH THE CHANGE OF ELEMENT BOUNDARY
MICHIHIRO NATORI (Tokyo, University, Sagamihara, Japan), YUZO SHIBAYAMA, and KOHJI SEKINE (NEC Corp., Yokohama, Japan) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1514-1521. refs
(AIAA PAPER 89-1332)

In future space reflector technology, active surface accuracy control is important to adapt the precise accuracy requirement. A concept of an active accuracy control of reflector surface through the change of element boundary planar shape for both an inflatable rigidized surface and a mesh surface augmented with elastic strips is introduced. The effectiveness of the concept is demonstrated through the deflection analysis of initially curved beam strips. It is shown that an appropriate change of element boundary distance improves the accuracy error very much. Author

A89-30821#
THE NEW DEPLOYABLE TRUSS CONCEPTS FOR LARGE ANTENNA STRUCTURES OR SOLAR CONCENTRATORS
K. A. TAKAMATSU (Fuji Heavy Industries, Ltd., Tochigi, Japan) and J. ONODA (Tokyo, University, Kanagawa, Japan) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1629-1639. refs
(AIAA PAPER 89-1346)

An account is given of the design features and deployment operation of three space frame systems applicable to the formation of large, spacecraft-stowable antennas and solar concentrators; these are designated a 'spatial diagonal-stiffened truss' (SDT), a 'sliding-hinge double-folder-II' (SHDF-II), and a 'deployable solar concentrator' (DSC). The SDT and SHDF-II are two-dimensional deployable truss structures, while the DSC additionally incorporates rigid reflector plates. The most significant feature of the DSC is the capability for automated deployment. Functioning models of all three structures have been successfully constructed and tested. O.C.

A89-31030* New Mexico State Univ., Las Cruces.
MODEM SIMULATIONS FOR POSSIBLE USE IN SPACE STATION
STEPHEN HORAN (New Mexico State University, Las Cruces) IN: ITC/USA/'88; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 17-20, 1988. Research Triangle Park, NC, Instrument Society of America, 1988, p. 431-436. Research supported by NASA. refs

Two candidate modem structures for use in the Space Station Multiple-Access Communications System were simulated using a software simulation package to obtain symbol error-rate curves. These systems represent an evolutionary QPSK-through-8 PSK modulation format for the input data streams. It was found that the use of phase-staggered QPSK modems would give lower expected implementation loss than a modem based upon the polarity-Costas-loop method. However, the latter would represent a simpler hardware investment to realize the modem structure for both QPSK and 8 PSK. Author

N89-10194*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SIMULTANEOUS S- AND X-BAND UPLINK-DOWNLINK PERFORMANCE AT DSS 13
A. J. FREILEY *In its* The Telecommunications and Data Acquisition Report p 93-101 15 Aug. 1988
Avail: NTIS HC A14/MF A01 CSCL 20N

The Deep Space Station 13 26-meter antenna with the second generation S/X feedcone was tested to determine the dual S- and X-band (2.1 to 2.3 GHz and 7.1 to 8.5 GHz) transmit and receive performance. Measurements were conducted using the 20 kW transmitters at S- and X-band while simultaneously receiving S- and X-band. This system proved to be very quiet compared with the other DSN antennas. Under normal tracking configurations, no noise burst or intermodulation product (IMP) activity was detectable to the -175 dBm level. To prove the instrumentation's ability to detect such phenomena, an IMP generator was introduced onto the system with positive, verifiable results. The IMP occurred at the -162 dBm level, accompanied by moderate noise burst activity, and was readily repeatable. The measurement also showed the possible need for additional fourth channel filtering in the system to reduce the effect of the transmitter power on the low noise amplifiers. Author

N89-18412*# California State Polytechnic Univ., Pomona. Dept. of Aerospace Engineering.
ISAAC: INFLATABLE SATELLITE OF AN ANTENNA ARRAY FOR COMMUNICATIONS, VOLUME 6 Final Report, 1987 - 1988
DEBORAH LODGARD, PATRICK ASHTON, MARGARET CHO, TOM CODIANA, RICHARD GEITH, SHARON MAYEDA, KIRSTEN NAGEL, and STEVEN SZE 11 Jun. 1988 117 p
(Contract NGT-21-002-080)
(NASA-CR-184704; NAS 1.26:184704) Avail: NTIS HC A06/MF A01 CSCL 01/2

The results of a study to design an antenna array satellite using rigid inflatable structure (RIS) technology are presented. An inflatable satellite allows for a very large structure to be compacted for transportation in the Space Shuttle to the Space Station where it is assembled. The proposed structure resulting from this study is a communications satellite for two-way communications with many low-power stations on the ground. Total weight is 15,438 kilograms which is within the capabilities of the Space Shuttle. The satellite will have an equivalent aperture greater than 100 meters in diameter and will be operable in K and C band frequencies, with a total power requirement of 10,720 watts. NASA

N89-18927# Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).
ADVANCED PHASED-ARRAY TECHNOLOGIES FOR SPACEBORNE APPLICATIONS
R. W. ZAHN and E. SCHMIDT *In* ESA, Proceedings of the 1988 International Geoscience and Remote Sensing Symposium (IGARSS) '88 on Remote Sensing: Moving Towards the 21st Century, Volume 2 p 1037-1038 Aug. 1988
Avail: NTIS HC A99/MF A01; ESA Publications Div. ESTEC, Noordwijk, Netherlands, $120 US or 250 Dutch guilders

Design aspects for a spaceborne active phased array synthetic aperture radar antenna are reviewed. A microstrip radiator with improved electrical and thermal performance is proposed. ESA

N89-19487# Joint Publications Research Service, Arlington, VA.
PEACEFUL USES OF ELECTRICAL ENGINEERING IN SPACE
N. N. SHEREMETYEVSKIY *In its* JPRS Report: Science and Technology. USSR: Electronics and Electrical Engineering p 20-28 30 Aug. 1988 Transl. into ENGLISH from Elektrotekhnika (Moscow, USSR), no. 6, Jun. 1987 p 10-16
Avail: NTIS HC A04/MF A01

In the 30 years since the world's first satellite was launched by the Soviet Union, space engineering has evolved into an independent field of science and engineering and one which is solving a broad range of scientific and technical problems concerning various branches of the national economy. Everyone knows of the Molniya and Raduga satellites, the Meteor weather satellites, the Salyut and Mir orbiting space stations and many others used to study near-earth and outer space, for radio and television broadcasting, weather forecasting and charting courses for ice-breakers. The collectives at the scientific research institutes and plants of the electrical equipment industry participate actively in solving the scientific-technical problems of space engineering. The branch has developed many tens of thousands of items for space engineering, including solar batteries, storage batteries, illumination engineering, cable products, and much more. Work done by electrical engineers to develop hardware components for orientation and power systems, automated systems, meteorology and resources-study is described and some important contributions to the peaceful use of space for the benefit of the Soviet people and all mankind are noted. Author

09

PROPULSION/FLUID MANAGEMENT

Includes descriptions, analyses, and subsystem requirements for propellant/fluid management and propulsion systems for attitude control and orbit maintenance and transfer for the station and supporting elements such as the OMV and OTV.

A89-10496
MODELLING, ANALYSIS AND CONTROL OF SLOSHING EFFECTS FOR SPACECRAFT UNDER ACCELERATION CONDITIONS
K. EBERT, CHR. ROCHE, and M. SURAUER (Messerschmitt-Boelkow-Blohm GmbH, Munich, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 78-82. (DGLR PAPER 87-093)

The analysis and control of sloshing in liquid-propellant tanks during spacecraft acceleration are discussed, with a focus on the fuel and oxidizer tanks of the DFS direct-broadcast and communication satellite. The DFS platform configuration and the z-axis acceleration involved in its apogee boost maneuver are characterized; the sloshing dynamics and equations of motion are analyzed; and a controller which is insensitive to system-parameter variations is derived on the basis of the state-observer principle for the body and sloshing, disturbance torque estimation/compensation, and panel attenuation filtering. Gain phase diagrams are presented for the plant open loop and the pitch control loop. T.K.

A89-12673* Lockheed Engineering and Management Services Co., Inc., Houston, TX.
TRAJECTORY ANALYSIS FOR LOW THRUST MANEUVERS AND DRAG DECAY IN LOW EARTH ORBIT OPERATIONS
W. D. KELLY (Lockheed Engineering and Management Services Co., Inc., Houston, TX) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 825-848. refs
(Contract NAS9-15800)
(AAS PAPER 87-475)

In the 1990s low earth orbit operations are anticipated which will include the Space Station and orbital maneuver vehicle (OMV) serviceable satellites requiring reboost and coordination despite drag decay and oblateness effects. A low thrust targeting algorithm is described applicable to Space Station and the OMV. Tests were made with Space Station reboost requirements and an oblate gravity model. The reboost requirements were determined based on projected station growth, atmospheric models and anticipated flight profiles. The targeting algorithm as well as the algorithm for predicting orbital decay are perturbation formulations of more 'transcendental' systems and are used in interactive personal computer simulations. Performance results and a discussion for the Space Station problems are provided. Author

A89-16543#
SPACE STATION - THE ORBITAL MANEUVERING VEHICLE
ARTHUR G. STEPHENSON (TRW, Inc., Cleveland, OH) Aerospace America (ISSN 0740-722X), vol. 26, Nov. 1988, p. 24-26, 28.

NASA's Orbital Maneuvering Vehicle (OMV) will augment Space Shuttle operations by retrieving and replacing satellites while expending far less propellant than the heavier manned vehicle would require. At the Space Station, the OMV will ferry logistics modules to and from the Shuttle's orbit some 130 n.m. below, deploy and dock OTVs, assemble modules, and retrieve satellites for servicing; it will then proceed to redeploy the satellites. OMV operations will be controlled either from the Shuttle or from a ground station, via video monitors. O.C.

A89-17661*# Booz-Allen and Hamilton, Inc., Arlington, VA.
SELECTION OF COMBINED WATER ELECTROLYSIS AND RESISTOJET PROPULSION FOR SPACE STATION FREEDOM
GEORGE R. SCHMIDT (Booz-Allen and Hamilton, Inc., Reston, VA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 17 p. refs
(Contract NASW-4300)
(IAF PAPER 88-067)

An analytical rationale is presented for the configuration of the NASA Space Station's two-element propulsion system, and attention is given to the cost benefits accruing to this system over the Space Station's service life. The principal system element uses gaseous oxygen and hydrogen obtained through water electrolysis to furnish attitude control, backup attitude control, and contingency maneuvering. The secondary element uses resistojets to augment Space Station reboost through the acceleration of waste gases in the direction opposite the Station's flight path. O.C.

A89-17710#
PROPULSION REQUIREMENTS FOR ORBITAL TRANSFER AND PLANETARY MISSION SUPPORT
JOHN B. CHAMBERS and S. E. DOYLE (Aerojet TechSystems Co., Sacramento, CA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 8 p. refs
(IAF PAPER 88-183)

The long-term storability, long-term stability, relative system mass, instant-cycle responsiveness, and reliability of hypergolic storable propellants are identified as critical characteristics in support of orbital transfer and planetary missions currently under consideration by planners for implementation over the next 20 years. The missions considered encompass, in addition to earth-to-orbit ones employing aerobraking, lunar missions from earth orbit, and Mars missions from earth orbit. O.C.

A89-17720*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EXPENDABLE LAUNCH VEHICLE TRANSPORTATION FOR THE SPACE STATION
ROBERT R. CORBAN (NASA, Lewis Research Center, Cleveland, OH) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 12 p. refs
(IAF PAPER 88-198)

ELVs are presently evaluated as major components of the NASA Space Station's logistics transportation system, augmenting the cargo capacity of the Space Shuttle in support of Station productivity and operational flexibility. The ELVs in question are the Delta II, Atlas II, Titan III, Titan IV, Shuttle-C (unmanned cargo development), European Ariane 5, and Japanese H-II, as well as smaller launch vehicles and OTVs. Early definition of ELV program impacts will preclude the potentially excessive costs of future Space Station modifications. O.C.

A89-17725*# National Aeronautics and Space Administration, Washington, DC.
THE ORBITAL MANEUVERING VEHICLE - A NEW CAPABILITY
CHARLES J. ARCILESI and CHARLES T. HOLLIMAN (NASA, Washington, DC) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 13 p. refs
(IAF PAPER 88-203)

NASA's Orbital Maneuvering Vehicle (OMV) is a reusable remotely-controlled spacecraft for support of orbiting platforms through such functions as satellite delivery, satellite retrieval, satellite reboost, controlled satellite deorbit, satellite inspection, and subsatellite missions. The OMV will be a critical component of the Space Station program's operational scenario; it will be able to operate either from the Space Shuttle Orbiter or the Space Station, and can also be space-based. The maiden flight of the first OMV is projected for 1993. O.C.

A89-17748#
A REAPPRAISAL OF SATELLITE ORBIT RAISING BY ELECTRIC PROPULSION
R. HOLDAWAY, Y. S. WONG (SERC, Rutherford Appleton Laboratory, Didcot, England), A. R. MARTIN, and P. M. LATHAM (U.K. Atomic Energy Authority, Culham Laboratory, Abingdon, England) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 5 p. refs
(IAF PAPER 88-261)

This paper makes an updated assessment of the technical and economic feasibility of transferring satellites from LEO to GEO using low thrust propulsion. In particular, the concept of a solar electric tug is discussed, whereby the main propulsion unit is returned from GEO to LEO for reuse. Author

A89-19678* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
AN ENVIRONMENT FOR THE INTEGRATION AND TEST OF THE SPACE STATION DISTRIBUTED AVIONICS SYSTEMS
THOMAS BARRY (NASA, Johnson Space Center, Houston, TX), TERRANCE SCHEFFER (McDonnell Douglas Astronautics Co., Saint Louis, MO), and L. R. SMALL (IBM Corp., System Integration Div., Houston, TX) IEEE Aerospace and Electronic Systems Magazine (ISSN 0885-8985), vol. 3, Nov. 1988, p. 16-20.

An approach to supplying an environment for the integration and test of the Space Station distributed avionics systems is described. Background is included on the development of this concept including the lessons learned from Space Shuttle experience. The environment's relationship to the process flow of the Space-Station verification, from systems development to on-orbit verification, is presented. The uses of the environment's hardware implementation, called Data Management System (DMS) kits, are covered. It is explained how these DMS kits provide a development version of the space-station operational environment

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and how this environment allows system developers to verify their systems performance, fault detection, and recovery capability. Conclusions on how the use of the DMS kits, in support of this concept, will ensure adequate on-orbit test capability are included. I.E.

A89-23258
SPACE TUG ON THE SLIPWAY
FRANK COLUCCI Space (ISSN 0267-954X), vol. 4, Mar.-Apr. 1988, p. 44-48.

The design, development, testing, and evaluation program for the NASA Orbital Maneuvering Vehicle (OMV) is discussed. The OMV configuration is described and illustrated. The development of techniques to refuel and repair the OMV and plans for payload interfaces, such as a grapple docking mechanism, are examined. Also, the operation of the OMV, the application of video techniques for docking and satellite inspection, and the possibility of modifying or expanding the OMV are considered. R.B.

A89-24495* RCA Aerospace and Defense, East Windsor, NJ.
ALL RESISTOJET CONTROL OF THE NASA DUAL KEEL SPACE STATION
M. A. PALUSZEK (RCA, Astro-Space Div., East Windsor, NJ) IN: Automatic control; Proceedings of the Tenth Triennial World Congress of IFAC, Munich, Federal Republic of Germany, July 27-31, 1987. Volume 6. Oxford, England and Elmsford, NY, Pergamon Press, 1988, p. 167-173. refs
(Contract NAS9-16023)

This paper describes a control system that uses small (0.1-N) hydrogen-fueled, high-expansion-ratio resistojets to control a Space Station's position and attitude. The number and size of the resistojets is calculated based on requirements for stationkeeping, compensation for steady-state gravity-gradient and aerodynamic torques, momentum loading due to mobile remote manipulator motion, Shuttle Orbiter docking, and translational evasive maneuvering. The all-resistojet control system performs continuous orbit maintenance while keeping the linear accelerations on the spacecraft lower than they would be without any control system operating. Author

A89-24901
RIDE AN ELEVATOR INTO SPACE
JEROME PEARSON (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) New Scientist (ISSN 0262-4079), vol. 121, Jan. 14, 1989, p. 58-61.

The concepts of space elevators and space tethers are considered. The possibility of constructing a tower to lift spacecraft into orbit and the theoretical use of electromagnetic forces to construct an orbital ring above the earth are discussed. Proposals for using space tethers are examined, including making measurements in the upper atmosphere in conjunction with the Space Shuttle, launching satellites from the Space Shuttle, collecting cargo from the lunar surface, and maintaining microgravity on the Space Station. R.B.

A89-25335*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE EFFECT OF INITIAL VELOCITY ON MANUALLY CONTROLLED REMOTE DOCKING OF AN ORBITAL MANEUVERING VEHICLE (OMV) TO A SPACE STATION
ADAM R. BRODY (NASA, Ames Research Center; Sterling Software, Aerospace Human Factor Research Div., Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(AIAA PAPER 89-0400)

Simulated docking maneuvers were performed to assess the effect of initial velocity on docking failure rate, mission duration, and total impulse (fuel consumption). The effect of the removal of the range and rate displays was also examined. Since duration and impulse decrease and increase respectively with increases in initial velocity, two parameters were created by subtracting a reference value from each. These values were termed 'reserve time' and 'radial impulse'. Naive subjects were capable of achieving a high success rate in performing simulated docking maneuvers without extensive experience, and failure rate did not significantly increase with increased velocity. The amount of time pilots reserved for final approach increased with starting velocity. Piloting of docking maneuvers was not significantly affected in any way by the removal of range and rate displays. Values for reserve time, and radial impulse were lowest for docking maneuvers begun at the lowest initial velocity. Author

A89-28273#
AENEAS - AN ESCAPE VEHICLE FOR THE INTERNATIONAL SPACE STATION [AENEAS - EEN ONTSNAPPINGSVOERTUIG VOOR HET INTERNATIONALE RUIMTESTATION]
J. MIES, E. MOOIJ, and J. OFFERMAN (Delft, Technische Universiteit, Netherlands) Ruimtevaart, vol. 37, Dec. 1988, p. 27-33. In Dutch.

The design concept of Aeneas, a crew emergency rescue vehicle (CERV) for the International Space Station, is discussed, summarizing the results of student feasibility studies undertaken at Delft Technical University in 1988. Plans call for two identical CERVs capable of returning six crew members to earth; major components include the capsule proper, a propulsion unit, cold-gas and hydrazine attitude-control jets, parachutes, and flotation equipment. Details of the CERV design and the integration with the Space Station are considered, and a mission profile is given. T.K.

A89-31895
MOVING THINGS ABOUT IN SPACE
ANDREW WILSON Interavia (ISSN 0020-5168), vol. 44, Feb. 1989, p. 155-158.

Space Shuttle Orbiter limitations and the evolution of ESA planning towards an independent manned-spacecraft program have prompted studies of an 'intelligent' upper stage for the Ariane 5 booster, in order to deliver heavy cargo modules to the NASA International Space Station and, eventually, ESA's own Man-Tended Free Flyer. This Ariane 5 Transfer Vehicle (ATV) is expected to draw as much as possible on the hardware of the Ariane L6 upper stage and Equipment Bay, in order to minimize costs. ATVs will probably remain attached to the Space Station for periods of up to six months, before returning laden with Station rubbish. NASA's OMV has from the outset been designed as a 'smart' stage, and will undertake a variety of missions during its 10-year design life. O.C.

N89-10119*# Rockwell International Corp., Canoga Park, CA. Rocketdyne Div.
ORBIT TRANSFER ROCKET ENGINE TECHNOLOGY PROGRAM. PHASE 2: ADVANCED ENGINE STUDY Interim Report
C. ERICKSON, A. MARTINEZ, and B. HINES Feb. 1987 85 p
(Contract NAS3-23773)
(NASA-CR-179602; NAS 1.26:179602; RI/RD-87-126) Avail: NTIS HC A05/MF A01 CSCL 21H

In Phase 2 of the Advanced Engine Study, the Failure Modes and Effects Analysis (FMEA) maintenance-driven engine design, preliminary maintenance plan, and concept for space operable disconnects generated in Phase 1 were further developed. Based on the results of the vehicle contractors Orbit Transfer Vehicle (OTV) Concept Definition and System Analysis Phase A studies, minor revisions to the engine design were made. Additional refinements in the engine design were identified through further engine concept studies. These included an updated engine balance incorporating experimental heat transfer data from the Enhanced Heat Load Thrust Chamber Study and a Rao optimum nozzle contour. The preliminary maintenance plan of Phase 1 was further developed through additional studies. These included a compilation of critical component lives and life limiters and a review of the Space Shuttle Main Engine (SSME) operations and maintenance manual in order to begin outlining the overall maintenance procedures for the Orbit Transfer Vehicle Engine and identifying technology requirements for streamlining space-based operations. Phase 2 efforts also provided further definition to the advanced

fluid coupling devices including the selection and preliminary design of a preferred concept and a preliminary test plan for its further development. Author

N89-11803*# Textron Bell Aerospace Co., Buffalo, NY.
SPACE STATION AUXILIARY THRUST CHAMBER TECHNOLOGY Final Report
J. M. SENNEFF Feb. 1987 44 p
(Contract NAS3-24883)
(NASA-CR-179650; NAS 1.26:179650; BELL-REPT-8911-950003)
Avail: NTIS HC A03/MF A01 CSCL 20/8

A program to design, fabricate, and test a 50 lb sub f (222 N) thruster was undertaken to demonstrate the applicability of the reverse flow concept as an item of auxillary propulsion for the Space Station. The thruster was to operate at a mixture ratio (O/F) of 4, be capable of operating for 2 million lb sub f-seconds (8.896 million N-seconds) impulse with a chamber pressure of 75 psia (52N/sq cm) and a nozzle area ratio of 40. A successful demonstration of an (0/F) of 4 thruster, was followed by the design objective of operating at (O/F) of 8. The demonstration of this thruster resulted in the order of and additional (O/F) of 8 thruster chamber under the present NAS 3-24883 contract. The effort to fabricate and test the second (0/F) of 8 thruster is documented. Author

N89-12022# Aeritalia S.p.A., Naples (Italy). Space Systems Group.
FLUID SCIENCE LABORATORY FOR COLUMBUS, EXECUTIVE SUMMARY
V. DEFILIPPI Paris, France ESA 31 Mar. 1988 45 p
(Contract ESA-6805/87)
(SG-RP-AI-024; ESA-CR(P)-2649; ETN-88-93245) Avail: NTIS HC A03/MF A01

The role of the fluid science laboratory (FSL) on Columbus; FSL scientific objectives; and Columbus resources and interfaces to FSL are summarized. The FSL concept comprises a fully contained fluid facility, a partially contained fluid facility, a containerless fluid facility, and a convection controlled fluid facility; two double racks; non dedicated containers for fluids, and conditioning loops; fully automated working; diagnostic techniques; and possibilities to intervene when changing fluids, diagnostics, stimuli, or geometric environmental conditions. A power conditioning subsystem is necessary. A man tended free flyer option is also feasible. ESA

N89-12581*# Martin Marietta Aerospace, Denver, CO. Space Station Program.
SPACE STATION INTEGRATED PROPULSION AND FLUID SYSTEMS STUDY
L. ROSE, D. BERGMAN, B. BICKNELL, and S. WILSON 25 Aug. 1987 77 p
(Contract NAS8-36438)
(NASA-CR-179393; NAS 1.26:179393; MCR-87-580) Avail: NTIS HC A05/MF A01 CSCL 22/2

This Databook addresses the integration of fluid systems of the Space Station program. It includes a catalog of components required for the Space Station elements fluid systems and information on potential hardware commonality. The components catalog is in four parts. The first part lists the components defined for all the fluid systems identified in EP 2.1, Space Station Program Fluid Systems Configuration Databook. The components are cross-referenced in three sections. Section 2.1 lists the components by the fluid system in which they are used. Section 2.2 lists the components by type. Section 2.3 lists by the type of fluid media handled by the component. The next part of the catalog provides a description of the individual component. This section (2.4) is made up of data retrieved from Martin Marietta Denver Aerospace component data base. The third part is an assessment of propulsion hardware technology requirements. Section 2.5 lists components identified during the study as requiring development prior to flight qualification. Finally, Section 2.6 presents the results of the evaluation of commonality between components. The specific requirements of each component have been reviewed and duplication eliminated. Author

N89-12843*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
TANK GAUGING APPARATUS AND METHOD Patent Application
BRIAN G. MORRIS, inventor (to NASA) 11 Jul. 1988 22 p
(NASA-CASE-MSC-21059-1; NAS 1.71:MSC-21059-1;
US-PATENT-APPL-SN-217725) Avail: NTIS HC A03/MF A01
CSCL 14/2

An apparatus for gauging the amount of liquid in a container of liquid and gas under low or zero gravity net conditions includes an accumulator and appropriate connector apparatus for communicating gas between the accumulator and the container. In one form of the invention, gas is removed from the container and compressed into the accumulator. The pressure and temperature of the fluid in the container is measured before and after removal of the gas; the pressure and temperature of the gas in the accumulator is measured before and after compression of the gas into the accumulator from the container. These pressure and temperature measurements are used to determine the volume of gas in the container, whereby the volume of the liquid in the container can be determined from the difference between the known volume of the container and the volume of gas in the container. Gas from the accumulator may be communicated into the container in a similar process as a verification of the gauging of the liquid volume, or as an independent process for determining the volume of liquid in the container. NASA

N89-13449*# Martin Marietta Corp., Denver, CO. Astronautics Group.
ORBITAL TRANSFER VEHICLE CONCEPT DEFINITION AND SYSTEM ANALYSIS STUDY, 1985. VOLUME 2: OTV CONCEPT DEFINITION AND EVALUATION. BOOK 2: OTV CONCEPT DEFINITION Final Report, Jul. 1984 - Oct. 1985
GLEN J. DICKMAN and J. T. KEELEY Oct. 1985 213 p Revised
(Contract NAS8-36108)
(NASA-CR-183543; NAS 1.26:183543;
MCR-86-2601-VOL-2-BK-2-REV) Avail: NTIS HC A10/MF A01
CSCL 22/2

This portion of the Orbit Transfer Vehicle (OTV) Concept Definition and System Analysis Study, Volume 2, Book 2, summarizes the flight vehicle concept selection process and results. It presents an overview of OTV mission and system design requirements and describes the family of OTV recommended, the reasons for this recommendation, and the associated Phase C/D Program. Author

N89-13451*# Martin Marietta Corp., Denver, CO. Astronautics Group.
ORBITAL TRANSFER VEHICLE CONCEPT DEFINITION AND SYSTEM ANALYSIS STUDY, 1986. VOLUME 1-A: EXECUTIVE SUMMARY SUPPLEMENT Final Report, Jul. 1984 - Oct. 1986
GLEN J. DICKMAN Apr. 1987 43 p Revised, July 1987
(Contract NAS8-36108)
(NASA-CR-183542; NAS 1.26:183542;
MCR-87-2601-VOL-1-A-REV) Avail: NTIS HC A03/MF A01
CSCL 22/2

This extension study has assessed the impact that the existence of a Large Cargo Vehicle and a variety of aggressive mission models would have on the preferred Orbital Transfer Vehicle Program. Author

N89-13454*# Martin Marietta Corp., Denver, CO. Astronautics Group.
ORBITAL TRANSFER VEHICLE CONCEPT DEFINITION AND SYSTEM ANALYSIS STUDY, 1986. VOLUME 9: STUDY EXTENSION RESULTS Final Report, Jan. - Sep. 1986
ALLEN E. KOFAL Jul. 1987 298 p Revised
(Contract NAS8-36108)

(NASA-CR-183549; NAS 1.26:183549; MCR-87-2601-VOL-9-REV) Avail: NTIS HC A13/MF A01 CSCL 22/2

The purpose of this extension to the OTV Concept Definition and Systems Analysis Study was to improve the definition of the OTV Program that will be most beneficial to the nation in the 1995 to 2010 timeframe. The implications of the defined mission and defined launch vehicle are investigated. The key mission requirements identified for the Space Transportation Architecture Study (STAS) were established and reflect a need for early capability and more ambitious capability growth. The key technical objectives and related issues addressed are summarized. The analyses of selected areas including aerobrake design, proximity operations, and the balance of EVA and IVA operations used in the support of the OTV at the space-base were enhanced. Sensitivity studies were conducted to establish how the OTV program should be tailored to meet changing circumstances. Author

N89-13458*# Martin Marietta Aerospace, Denver, CO.
ORBITAL TRANSFER VEHICLE CONCEPT DEFINITION AND SYSTEM ANALYSIS STUDY. VOLUME 2: OTV CONCEPT DEFINITION AND EVALUATION. BOOK 3: SUBSYSTEM TRADE STUDIES
GLEN J. DICKMAN Jul. 1987 431 p Revised
(Contract NAS8-36108)
(NASA-CR-183544; NAS 1.26:183544; MCR-86-2601-VOL-2-BK-3-REV) Avail: NTIS HC A19/MF A01 CSCL 22/2

The technical trade studies and analyses reported in this book represent the accumulated work of the technical staff for the contract period. The general disciplines covered are as follows: (1) Guidance, Navigation, and Control; (2) Avionics Hardware; (3) Aeroassist Technology; (4) Propulsion; (5) Structure and Materials; and (6) Thermal Control Technology. The objectives in each of these areas were to develop the latest data, information, and analyses in support of the vehicle design effort. Author

N89-13786* National Aeronautics and Space Administration. John F. Kennedy Space Center, Cocoa Beach, FL.
QUICK-DISCONNECT INFLATABLE SEAL ASSEMBLY Patent
KURT D. BUEHLER, inventor (to NASA) and JAMES E. FESMIRE, inventor (to NASA) 20 Sep. 1988 9 p Filed 22 May 1987 Supersedes N87-25583 (25 - 19, p 2616)
(NASA-CASE-KSC-11368-1; US-PATENT-4,772,050; US-PATENT-APPL-SN-052940; US-PATENT-CLASS-285-39; US-PATENT-CLASS-285-97; US-PATENT-CLASS-285-107; US-PATENT-CLASS-285-108; US-PATENT-CLASS-285-109; US-PATENT-CLASS-285-133.1; US-PATENT-CLASS-285-351) Avail: US Patent and Trademark Office CSCL 13/11

This invention concerns an inflatable seal assembly adapted for use with a bayonet quick-disconnect system particularly useful for the insulated transfer of cryogenic consumables in orbit (such as between a space station and a re-supply vehicle). The zero-leak cryogenic coupling includes a polymeric seal clamped to a male bayonet member with two pairs of tightening rings. The tightening rings threadably engage each other in respective pairs around tapered ends of the inflatable seal member so that a wedging action tightens the seal member about the male bayonet. Once in place, the seal may be inflated via an inflation port so that its expansion provides pressure contact with the inside surface of a coaxial female member.
Official Gazette of the U.S. Patent and Trademark Office

N89-15154*# Martin Marietta Aerospace, Denver, CO. Astronautics Group.
SPACE STATION INTEGRATED PROPULSION AND FLUID SYSTEMS STUDY Final Report
B. BICKNELL, S. WILSON, M. DENNIS, D. SHEPARD, and R. ROSSIER Sep. 1988 106 p
(Contract NAS8-36438)
(NASA-CR-183509; NAS 1.26:183509; MCR-88-539) Avail: NTIS HC A06/MF A01 CSCL 22/2

The program study was performed in two tasks: Task 1 addressed propulsion systems and Task 2 addressed all fluid systems associated with the Space Station elements, which also included propulsion and pressurant systems. Program results indicated a substantial reduction in life cycle costs through integrating the oxygen/hydrogen propulsion system with the environmental control and life support system, and through supplying nitrogen in a cryogenic gaseous supercritical or subcritical liquid state. A water sensitivity analysis showed that increasing the food water content would substantially increase the amount of water available for propulsion use and in all cases, the implementation of the BOSCH CO2 reduction process would reduce overall life cycle costs to the station and minimize risk. An investigation of fluid systems and associated requirements revealed a delicate balance between the individual propulsion and fluid systems across work packages and a strong interdependence between all other fluid systems. Author

N89-15159# Sandia National Labs., Albuquerque, NM.
EXPERIMENTAL OBSERVATIONS OF LOW AND ZERO GRAVITY NONLINEAR FLUID-SPACECRAFT INTERACTION
L. D. PETERSON 1988 24 p Presented at the 59th Shock and Vibration Symposium, Albuquerque, NM, 18 Oct. 1988
(Contract DE-AC04-76DP-00789)
(DE88-015263; SAND-88-1520C; CONF-881076-6) Avail: NTIS HC A03/MF A01

Low and zero gravity simulation experiments of the motion of a spacecraft coupled to the nonlinear slosh of a contained fluid are presented and discussed. A generic study model, in which a linear, spring-mass-damper spacecraft mode was coupled to the slosh of a fluid within an attached cylinder, has been studied experimentally using a unique, scale model apparatus. Low gravity was simulated in a 1 g laboratory using capillary (Bond number) scaled models, and zero gravity was simulated during experiments on the NASA KC-135 Reduced Gravity Test Facility. The mass fraction of fluid, the tuning ratio of the fluid and spacecraft vibrations, the spacecraft damping ratio, and the nondimensional gravity level were systematically varied. The nonlinear free decay response of the experimental systems exhibited system natural frequencies which varied in proportion to the square of the amplitude of the motion. The nonlinear resonance responses displayed harmonic, nonharmonic, planar, nonplanar, and spatially chaotic motions. These experimental responses can only be modeled by a nonlinear analytical model of the fluid coupled to the spacecraft model, and cannot be predicted by the simple linear slosh models now in use. DOE

N89-15969*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Aerospace and Ocean Engineering.
SPACE-BASED LASER-POWERED ORBITAL TRANSFER VEHICLE (PROJECT SLICK)
Jun. 1988 225 p
(Contract NGT-21-002-080; NGT-80001)
(NASA-CR-184716; NAS 1.26:184716) Avail: NTIS HC A10/MF A01 CSCL 22/2

A conceptual design study of a laser-powered orbital transfer vehicle (LOTV) is presented. The LOTV, nicknamed SLICK (Space Laser Interorbital Cargo Kite), will be utilized for the transfer of 16000 kg of cargo between Low Earth Orbit (LEO) and either Geosynchronous Earth Orbit (GEO) or Low Lunar Orbit (LLO). This design concentrates primarily on the LEO/GEO scenario, which will have typical LEO-to-GEO trip time of 6 days and two return versions. One version uses an all propulsive return while the other utilizes a ballute aerobrake for the return trip. Furthermore, three return cargo options of 16000 kg, 5000 kg (standard option), and 1600 kg are considered for this scenario. The LEO/LLO scenario uses only a standard, aerobraked version. The basic concept behind the LOTV is that the power for the propulsion system is supplied by a source separate from the LOTV itself. For the LEO/GEO scenario the LOTV utilizes a direct solar-pumped iodide laser and possibly two relay stations, all orbiting at an altitude of one Earth radius and zero inclination. An additional nuclear-powered laser is placed on the Moon for the LEO/LLO scenario. The propulsion system of the LOTV consists of a single

engine fueled with liquid hydrogen. The laser beam is captured and directed by a four mirror optical system through a window in the thrust chamber of the engine. There, seven plasmas are created to convert the laser beam energy into thermal energy at an efficiency of at least 50 percent. For the LEO/LLO scenario the laser propulsion is supplemented by LH2/LOX chemical thrusters. Author

N89-16357*# Houston Univ., Clear Lake, TX.
MODELING, SIMULATION AND CONTROL FOR A CRYOGENIC FLUID MANAGEMENT FACILITY, PRELIMINARY REPORT
MAX A. TURNER and P. D. VANBUSKIRK (Lockheed Missiles and Space Co., Burbank, CA.) *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 12 p 1986
Avail: NTIS HC A22/MF A01 CSCL 09/2

The synthesis of a control system for a cryogenic fluid management facility was studied. The severe demand for reliability as well as instrumentation and control unique to the Space Station environment are prime considerations. Realizing that the effective control system depends heavily on quantitative description of the facility dynamics, a methodology for process identification and parameter estimation is postulated. A block diagram of the associated control system is also produced. Finally, an on-line adaptive control strategy is developed utilizing optimization of the velocity form control parameters (proportional gains, integration and derivative time constants) in appropriate difference equations for direct digital control. Of special concern are the communications, software and hardware supporting interaction between the ground and orbital systems. It is visualized that specialist in the OSI/ISO utilizing the Ada programming language will influence further development, testing and validation of the simplistic models presented here for adaptation to the actual flight environment. Author

N89-17613*# Martin Marietta Aerospace, Denver, CO. Astronautics Group.
SPACE STATION INTEGRATED PROPULSION AND FLUID SYSTEMS STUDY. SPACE STATION PROGRAM FLUID MANAGEMENT SYSTEMS DATABOOK
B. BICKNELL, S. WILSON, M. DENNIS, and M. LYDON 26 Apr. 1988 231 p
(Contract NAS8-36438)
(NASA-CR-183583; NAS 1.26:183583; MCR-88-557) Avail: NTIS HC A11/MF A01 CSCL 22/2

Commonality and integration of propulsion and fluid systems associated with the Space Station elements are being evaluated. The Space Station elements consist of the core station, which includes habitation and laboratory modules, nodes, airlocks, and trusswork; and associated vehicles, platforms, experiments, and payloads. The program is being performed as two discrete tasks. Task 1 investigated the components of the Space Station architecture to determine the feasibility and practicality of commonality and integration among the various propulsion elements. This task was completed. Task 2 is examining integration and commonality among fluid systems which were identified by the Phase B Space Station contractors as being part of the initial operating capability (IOC) and growth Space Station architectures. Requirements and descriptions for reference fluid systems were compiled from Space Station documentation and other sources. The fluid systems being examined are: an experiment gas supply system, an oxygen/hydrogen supply system, an integrated water system, the integrated nitrogen system, and the integrated waste fluids system. Definitions and descriptions of alternate systems were developed, along with analyses and discussions of their benefits and detriments. This databook includes fluid systems descriptions, requirements, schematic diagrams, component lists, and discussions of the fluid systems. In addition, cost comparison are used in some cases to determine the optimum system for a specific task. Author

N89-18506*# Virginia Univ., Charlottesville.
CONCEPTUAL DESIGN OF A MANNED ORBITAL TRANSFER VEHICLE Final Report
RICHARD DAVIS, MILES DUQUETTE, REBECCA FREDRICK, DANIEL SCHUMACHER, SCHAEFFER SOMERS, STANLEY STAFIRA, JAMES WILLIAMS, and MARK ZELINKA May 1988 192 p
(Contract NGT-21-002-080)
(NASA-CR-183391; NAS 1.26:183391) Avail: NTIS HC A09/MF A01 CSCL 22/2

With the advent of the manned space station, man now requires a spacecraft based on the space station with the ability to deploy, recover, and repair satellites quickly and economically. Such a craft would prolong and enhance the life and performance of many satellites. A basic design was developed for an orbital tansfer vehicle (OTV). The basic design criteria are discussed. The design of the OTV and systems were researched in the following areas: avionics, crew systems, electrical power systems, environmental control/life support systems, navigation and orbital maneuvers, propulsion systems, reaction control systems (RCS), servicing systems, and structures. The basic concepts in each of the areas are summarized. B.G.

N89-18517*# McDonnell-Douglas Astronautics Co., Huntington Beach, CA.
BERTHING MECHANISM FINAL TEST REPORT AND PROGRAM ASSESSMENT
Oct. 1988 90 p Prepared in cooperation with Control Dynamics Co., Huntsville, AL
(Contract NAS8-36417)
(NASA-CR-183554; NAS 1.26:183554; MDAC-H3913; CDRL-13; CDRL-14) Avail: NTIS HC A05/MF A01 CSCL 22/2

The purpose is to document the testing performed on both hardware and software developed under the Space Station Berthing Mechanisms Program. Testing of the mechanism occurred at three locations. Several system components, e.g., actuators and computer systems, were functionally tested before assembly. A series of post assembly tests were performed. The post assembly tests, as well as the dynamic testing of the mechanism, are presented. Author

N89-19337# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.
MANEUVERING EQUATIONS IN TERMS OF QUASI-COORDINATE
LEONARD MEIROVITCH *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 19-21 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

The equations for the motion of a flexible spacecraft in space can be described conveniently in terms of quasi-coordinates. The nonlinear equations can be treated by a perturbation approach, resulting in a low-order nonlinear problem for the rigid-body maneuvering and linear time-varying problem for angular perturbations from the rigid-body maneuver and elastic vibration. Author

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MECHANISMS, AUTOMATION, AND ARTIFICIAL INTELLIGENCE

Includes descriptions of simulations, models, analytical techniques, and requirements for remote, automated and robotic mechanical systems.

A89-10492
AUTOMATION AND ROBOTICS IN SPACE [AUTOMATION UND ROBOTIK IM WELTRAUM]
E. FREUND (Dortmund, Universitaet, Federal Republic of

Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 54-60. In German. refs
(DGLR PAPER 87-096)

The current status of robotics for space applications is surveyed and illustrated with diagrams and drawings, and strategies for future R&D efforts are examined with reference to the FRG Planning Framework for High Technology and Space Flight (OHR). The design structure of a typical manipulator system is outlined; the degree of robot control needed for different space missions (ranging from telepresence and teleoperation to fully autonomous operation) is discussed; and the control-theoretical problem of trajectory determination for three robots and one work platform in free flight is briefly considered. The key technologies to be developed within the OHR include lightweight intelligent sensor-guided manipulators, modular gripping systems and wide-application tools, improved man-machine interfaces, increased decision-making and planning capabilities via knowledge-based systems, and coordination of multiple-armed robots and multiple-robot configurations. T.K.

A89-10596* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
LANGLEY RESEARCH CENTER RESOURCES AND NEEDS FOR MANNED SPACE OPERATIONS SIMULATION
ROBERT R. NUNAMAKER and LAWRENCE F. ROWELL (NASA, Langley Research Center, Hampton, VA) IN: Aerospace Behavioral Engineering Technology Conference, 6th, Long Beach, CA, Oct. 5-8, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 189-197. refs
(SAE PAPER 871724)

This paper describes current simulation research activities carried out at the Langley Research Center in the areas of remotely controlled operations, task performance, and analytical operations, along with early simulators developed at the center. Special attention is given to the center's current space simulation capabilities which are applicable to manned space operation studies, including the Advanced Concepts Simulator (ACS) and a computer-generated imagery (CGI). The ACS was designed to represent an aircraft cockpit for flight operations in the 1990s but will be also suitable for simulating a variety of astronaut work station applications. The CGI, scheduled for delivery in 1989, will be able to provide out-the-window scenes representative of many operational tasks from rendezvous and docking/berthing to control of telerobotic devices. I.S.

A89-10666
FUTURE DIRECTIONS IN SPACECRAFT MECHANISMS TECHNOLOGY
STUART H. LOEWENTHAL and W. E. LOMAS, II (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) IN: International Pacific Air and Space Technology Conference, Melbourne, Australia, Nov. 13-17, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 453-465. refs
(SAE PAPER 872454)

This paper presents a reflective survey of recent developments in spacecraft mechanism technology, focussing on analytical tools, precision gimbal and robotics technologies. These topical areas were highlighted because they are good indicators where new mechanism technology is emerging. Today's mechanical dynamic simulation software permits routine solution of a large class of separation mechanism problems, yielding important time dependent, joint forces and motion information. The requirements for pointing multithousand kilogram scientific payloads to multiarc second levels aboard Space Station is extending gimbal technology. An innovative concept for isolating gimbal payloads from base motion disturbances is described. The goal of augmenting man's capability in space through robotics has virtually spawned a new industry. However, the transition between industrial and space robotic systems is not a particularly easy one, as discussed in this review. Author

A89-11682*# Case Western Reserve Univ., Cleveland, OH.
ROBOTS FOR MANIPULATION IN A MICRO-GRAVITY ENVIRONMENT
R. D. QUINN (Case Western Reserve University, Cleveland, OH) and C. LAWRENCE (NASA, Lewis Research Center, Cleveland, OH) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 515-528. refs

This paper is concerned with the development of control strategies and mechanisms for robots operating in the micro-gravity environment of Space Station. These robots must be capable of conducting experiments and manufacturing processes without disturbing the micro-gravity environment through base reactions/motion. Approaches discussed for controlling the robot base reactions/motions include strategies making use of manipulators with redundant degrees of freedom, actuators at the robot base, and a redundant (balancing) arm. Two degree-of-freedom, traction-drive joints are discussed as well as the conceptual design for a traction-driven manipulator. Author

A89-11688#
DYNAMICS OF A FLEXIBLE ORBITING PLATFORM WITH MRMS
Y. MORITA, H. YOKOTA (Tokyo, University, Japan), and V. J. MODI (British Columbia, University, Vancouver, Canada) IN: Dynamics and control of large structures; Proceedings of the Sixth VPI&SU/AIAA Symposium, Blacksburg, VA, June 29-July 1, 1987. Blacksburg, VA, Virginia Polytechnic Institute and State University, 1988, p. 631-646. refs

A relatively general formulation for studying the dynamics of a flexible Mobile Remote Manipulator System (MRMS), supported by an orbiting flexible platform, is developed using the Lagrangian approach, with generalized forces accounting for the environmental effects, damping, and control. The effectiveness of the general formulation is demonstrated by analyzing complex interactions between vibrational and librational degrees of freedom in the presence of MRMS maneuver over a range of system parameters and initial conditions. It is shown that translational and slewing maneuver of the MRMS substantially affects the librational response of the platform due to a shift in the center of mass and transient character of the inertia matrix. V.L.

A89-11803
SPACE STATION AUTOMATION III; PROCEEDINGS OF THE MEETING, CAMBRIDGE, MA, NOV. 2-4, 1987
WUN C. CHIOU, SR., ED. Meeting sponsored by SPIE, IEEE, NASA, et al. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Volume 851), 1987, 192 p. For individual items see A89-11804 to A89-11828.
(SPIE-851)

The conference presents papers on the application of artificial intelligence technology to national space programs, system and subsystem autonomy, telerobotic technology for space applications, and remote servicing platforms. Topics include testing and validation in artificial intelligence programming, common sense knowledge framework for subsystem autonomy, mission planning and simulation via intelligent agents, and system autonomy hooks and scars for Space Station. Consideration is also given to sensor integration by system and operator, intelligent training system for payload-assist module deploys, telerobot experiment concepts in space, common sense planning applied to grasping and manipulating, and Space Station flight telerobotic servicer functional requirements development. K.K.

A89-11816* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
TELEROBOT EXPERIMENT CONCEPTS IN SPACE
LYLE M. JENKINS (NASA, Johnson Space Center, Houston, TX) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 92-94.

A unique set of problems will be encountered in the development

of telerobotic systems for space applications such as the Flight Telerobotic System. The dexterous manipulation of objects in zero g will be significantly different. Issues arise from mechanical response and operator interaction with the controls and displays. To reduce development risk, a series of experiments are conceived for the Space Shuttle. Author

A89-11818* Carnegie-Mellon Univ., Pittsburgh, PA.
PLANNING ASSEMBLY/DISASSEMBLY OPERATIONS FOR SPACE TELEROBOTICS
ARTHUR C. SANDERSON and LUIZ HOMEM DE MELLO (Carnegie-Mellon University, Pittsburgh, PA) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 109-115. Research supported by the Conselho Nacional de Desenvolvimento Cientifico e Tecnologico of Brazil, Carnegie-Mellon University, and NASA. refs

Space telerobotic systems will perform complex tasks of assembly, disassembly, and repair of space-based equipment. Planning such tasks requires reasoning about the functional, physical, and geometrical properties of the equipment, as well as a representation of the characteristics and capabilities of the manipulators and sensors available for the task. The And/Or graph is a useful approach to representation of feasible assembly/disassembly sequences and provides the basis for search among alternative strategies. The paper describes the use of parts entropy measures as evaluation criteria for search in the And/Or graph space. This approach leads to candidate task plans which minimize the complexity of intermediate geometrical states. Author

A89-11825* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
AUTOMATION AND ROBOTICS AND RELATED TECHNOLOGY ISSUES FOR SPACE STATION CUSTOMER SERVICING
HELMUT P. CLINE (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 161-168.

Several flight servicing support elements are discussed within the context of the Space Station. Particular attention is given to the servicing facility, the mobile servicing center, and the flight telerobotic servicer (FTS). The role that automation and robotics can play in the design and operation of each of these elements is discussed. It is noted that the FTS, which is currently being developed by NASA, will evolve to increasing levels of autonomy to allow for the virtual elimination of routine EVA. Some of the features of the FTS will probably be: dual manipulator arms having reach and dexterity roughly equivalent to that of an EVA-suited astronaut, force reflection capability allowing efficient teleoperation, and capability of operating from a variety of support systems. K.K.

A89-11826* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
SPACE STATION FLIGHT TELEROBOTIC SERVICER FUNCTIONAL REQUIREMENTS DEVELOPMENT
JOHN OBERRIGHT, HARRY MCCAIN (NASA, Goddard Space Flight Center, Greenbelt, MD), and RUTH I. WHITMAN (ORI, Inc., Systems Planning Div., Rockville, MD) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 169-172.

The Space Station flight telerobotic servicer (FTS), a flight robotic system for use on the first Space Station launch, is described. The objectives of the FTS program include: (1) the provision of an alternative crew EVA by supporting the crew in assembly, maintenance, and servicing activities, and (2) the improvement of crew safety by performing hazardous tasks such as spacecraft refueling or thermal and power system maintenance. The NASA/NBS Standard Reference Model provides the generic, hierarchical, structured functional control definition for the system. It is capable of accommodating additional degrees of machine intelligence in the future. K.K.

A89-11901
1988 IEEE INTERNATIONAL CONFERENCE ON ROBOTICS AND AUTOMATION, PHILADELPHIA, PA, APR. 24-29, 1988, PROCEEDINGS. VOLUMES 1, 2, & 3
Conference sponsored by IEEE. Washington, DC, Computer Society Press, 1988, p. Vol. 1, 687 p.; vol. 2, 701 p.; vol. 3, 588 p. For individual items see A89-11902 to A89-11927, A89-11929 to A89-12069.

Various papers on robotics and automation are presented. The general topics addressed include: flexible manipulators; redundant robots; trajectory planning; grasping; mechanisms and actuators; neurocomputing in robotics; computer architectures in robotics; multiarm robots; motion planning; intelligent mobile systems; inverse kinematics; adaptive manipulator control methods; tactile sensing; robot calibration; legged locomotion; adaptive control of robots; representation for planning; modeling and perception; robot dynamics and control; adaptive control: gross motion; planning and control; multisensor fusion; assembly: object representation; control of robot manipulators; navigation: position estimation; assembly: parts interaction; automatic process planning; and feedback control. Also discussed are: robot arm dynamics; recognition and inspection; friction and vibration; industrial applications; force control; modeling and simulation; two-dimensional vision; assembly applications; hybrid position and force control; motion planning with obstacles; modeling and control; three-dimensional range sensing; understanding and programming; sensing applications; model-based motion planning; stereo vision. C.D.

A89-11905
MODELLING OF A 5-BAR-LINKAGE MANIPULATOR WITH ONE FLEXIBLE LINK
DAVID WANG and M. VIDYASAGAR (Waterloo, University, Canada) IN: 1988 IEEE International Conference on Robotics and Automation, Philadelphia, PA, Apr. 24-29, 1988, Proceedings. Volume 1. Washington, DC, Computer Society Press, 1988, p. 21-26. refs

A model of a five-bar-linkage robot is examined where the top link is flexible. The modeling process is described and applied to the simpler problem of a single link beam. The model of the five-bar-linkage robot with the top link flexible is derived and then simplified using various assumptions which are discussed. It is shown that under these assumptions, it may be possible to control two joints using a typical rigid-body controller while using the third joint to control the vibrations. This greatly simplifies the control problem. I.E.

A89-12005* Massachusetts Inst. of Tech., Cambridge.
TRACKING AND STATIONKEEPING FOR FREE-FLYING ROBOTS USING SLIDING SURFACES
CRAIG R. CARIGNAN (STX Corp., Lanham, MD) and DAVID L. AKIN (MIT, Cambridge, MA) IN: 1988 IEEE International Conference on Robotics and Automation, Philadelphia, PA, Apr. 24-29, 1988, Proceedings. Volume 2. Washington, DC, Computer Society Press, 1988, p. 969-974. refs
(Contract NAGW-21)

The authors use the concept of sliding surfaces for generating two types of tracking control laws for a free-flying robot engaged in zero-gravity assembly tasks. Suction control, developed elsewhere for controlling manipulators with stationary bases, is used here to track workspace trajectories for manipulators mounted on mobile platforms. Zone control is formulated for the purpose of stationkeeping a robot maneuvering unit during payload manipulation. Experimental results are described for tests performed on an air-bearing robot tracking payload trajectories along a glass surface. I.E.

A89-12026
REAL-TIME OBJECT DETERMINATION FOR SPACE ROBOTICS
GORDON T. UBER and MARK F. DOHERTY (Lockheed Digital Image Processing Laboratory, Palo Alto, CA) IN: 1988 IEEE International Conference on Robotics and Automation, Philadelphia, PA, Apr. 24-29, 1988, Proceedings. Volume 2. Washington, DC, Computer Society Press, 1988, p. 1320, 1321. refs

The successful creation of an autonomous space robot for on-orbit satellite servicing and inspection depends greatly upon the vision understanding subsystem. Off-the-shelf vision systems do not provide the three spatial and one temporal dimension modeling necessary for this complex task. Prior research has generally investigated the four-dimensional scene understanding problem at the expense of a true real-time capability. The authors have begun research at the Lockheed Digital Image Processing Laboratory on a space robot vision subsystem providing both a real-time processing and four-dimensional object determination. The authors describe their initial approach. I.E.

A89-12068* Carnegie-Mellon Univ., Pittsburgh, PA.
PLANNING REPAIR SEQUENCES USING THE AND/OR GRAPH REPRESENTATION OF ASSEMBLY PLANS
L. S. HOMEM DE MELLO (Carnegie-Mellon University, Pittsburgh, PA) and A. C. SANDERSON (Rensselaer Polytechnic Institute, Troy, NY) IN: 1988 IEEE International Conference on Robotics and Automation, Philadelphia, PA, Apr. 24-29, 1988, Proceedings. Volume 3. Washington, DC, Computer Society Press, 1988, p. 1861, 1862. Research supported by the Conselho Nacional de Desenvolvimento Cientifico e Tecnologico of Brazil, Carnegie-Mellon University, and NASA. refs

A simple modification is shown in the set of goal nodes of the AND/OR graph that allows its use in planning repairs such as the replacement of a part or a subassembly. An algorithm for the generation of all feasible sequences for disassembly and reassembly of parts that will achieve a repair is shown. This approach has been demonstrated for the example of the repair of space-based satellite equipment. I.E.

A89-12677
DYNAMICS DURING SLEWING AND TRANSLATIONAL MANEUVERS OF THE SPACE STATION BASED MRMS
H. W. MAH, V. J. MODI (British Columbia, University, Vancouver, Canada), Y. MORITA, and H. YOKOTA (Tokyo, University, Japan) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 2. San Diego, CA, Univelt, Inc., 1988, p. 915-933.
(Contract NSERC-G-1547)
(AAS PAPER 87-481)

A formulation for studying the librational dynamics of a flexible platform supporting a mobile base connected to a series of slewing flexible appendages is presented. This formulation is ideally suited for the dynamics and control analysis of the Space Station based Mobile Remote Manipulator System (MRMS); it should prove useful during preliminary planning of the Space Station integration and operation. It is shown that the translational motion and the slewing maneuver of the MRMS influence the librational response of the platform due to a shift in the system center of mass and the transient character of the satellite inertia matrix. K.K.

A89-15115
TASKS PROJECTED FOR SPACE ROBOTS AND AN EXAMPLE OF ASSOCIATED ORBITAL INFRASTRUCTURE [TACHES ENVISAGEES POUR LES ROBOTS SPATIAUX ET EXEMPLE D'INFRASTRUCTURE ORBITALE ASSOCIEE]
P. DUTTO (CNES, Toulouse, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 131, 1988, p. 12-20. In French.

Following a review of the orbital infrastructure projected up to the beginning of the 21st century, the application of robotics to manned and unmanned missions is discussed. Particular attention is given to the Space Station, MIR, the attached presurized module, Hermes, and Ariane V. The use of AI to increase the level of autonomy and automation of space systems is considered. Possible roles for robotic systems include routine activities on manned and unmanned space flights, the execution of dangerous tasks (such as those on platforms exposed to elevated radiation levels or those involving nuclear reactors), and probing on distant missions. R.R.

A89-16521#
ROBOTIC SERVICING OF THE SPACE STATION PLATFORM
A. R. FROHBIETER, S. W. JACKSON, R. G. KOCINSKI, and W. E. STONEY (General Electric Co., Astro-Space Div., Princeton, NJ) AIAA, Space Programs and Technologies Conference, Houston, TX, June 21-24, 1988. 14 p.
(AIAA PAPER 88-3497)

The baseline NASA Space Station Polar Orbiting Platform (POP) design included in-orbit Space Shuttle EVA or robotic servicing over a 15-year operational lifetime. A study has been conducted to ascertain the feasibility of relieving the Shuttle fleet of these POP services through the use of ELVs in conjunction with robotic operations. It is found that existing ELVs are suitable for these servicing operations, using remotely supervised robotics. O.C.

A89-17632*# Payload Systems, Inc., Wellesley, MA.
TELESCIENCE SPACE LIFE SCIENCES TEST BED
VINIT NIJHAWAN, BYRON K. LICHTENBERG (Payload Systems, Inc., Wellesley, MA), WILLIAM R. MUNSEY (NASA, Kennedy Space Center, Cocoa Beach, FL), CHARLES M. OMAN, and LAURENCE R. YOUNG (MIT, Cambridge, MA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 5 p.
(IAF PAPER 88-014)

This paper discusses the life sciences test bed project to evaluate the methodology for conducting a life sciences experiment over real physical distance with voice, video, and data interaction between the experiment and the remotely located investigators. The project was planned to identify the requirements for the Space Station Information System for life sciences experiments. The experiment design is presented, including video, data, and voice links. The ground based principal investigator workstation and the telescience operations are examined. R.B.

A89-17633#
TELESCIENCE AND MICROGRAVITY - IMPACT ON FUTURE FACILITIES, GROUND SEGMENTS AND OPERATIONS
R. MONTI (Napoli, Universita, Naples, Italy) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 17 p.
(IAF PAPER 88-015)

The use of telescience as the preparatory phase for the future exploitation of microgravity by means of expert systems is reviewed. Ground segment structure, user support centers organization, and test bedding activities are discussed. Special attention is given to the role of the ground based primary investigator in conducting microgravity experiments on permanent space platforms. The use of telescience in the Columbus project is considered. R.B.

A89-17656#
CANADA'S MOBILE SERVICING SYSTEM FOR SPACE STATION
W. E. M. EVANS (Ministry of State for Science and Technology, Canada) and K. H. DOETSCH (National Research Council of Canada, Ottawa) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 8 p. refs
(IAF PAPER 88-057)

The development program for the Mobile Sevicing System (MSS) of the Space Station is discussed. The on-orbit elements of the MSS are examined, including the Mobile Servicing Center, the MSS Maintenance Depot, and the Special Purpose Dexterous Manipulator. Ground support facilities and technology development for the MSS are considered. R.B.

A89-17670#
MOBILE SERVICING SYSTEM FLIGHT OPERATIONS AND SUPPORT

D. A. BASSETT (National Research Council of Canada, Ottawa), J. A. MIDDLETON, W. J. G. BRIMLEY, and T. W. YOUNG (SPAR Aerospace, Ltd., Toronto, Canada) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 33 p.
(IAF PAPER 88-086)

The Mobile Servicing System (MSS), Canada's contribution to the International Space Station Program will perform a vital role in the on-orbit operations of the Space Station. This role will include activities in Assembly, Maintenance, Attached Payload Servicing, and Berthing/deberthing operations. This paper provides a description of the operations role of the MSS in the Assembly Sequence of the International Space Station. The launch sequence and on-orbit checkout and integration of the early elements of the MSS will be described in detail. Berthing and cargo transfer operations between the MSS and the STS Orbiter will be discussed as will operations scenarios during the early assembly sequence. The support and training efforts in support of early operations are discussed, and a description of the Canadian Operations support facilities are provided. Author

A89-17837#
AUTOMATION AND ROBOTICS ONBOARD EUROPEAN SPACE LABORATORY MODULES
K.-P. LUDWIG (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 7 p. refs
(IAF PAPER 88-488)

This paper describes the rationale, criteria, and resulting concept for experiment automation within the pressurized laboratories of current and future European space programs. A description of the pressurized laboratories under investigation is given, and the expected payload character and the problems in experiment operations by crewmen are outlined. Using the APM as an example for future European laboratories, the necessity of introducing A&R systems into payload operations is deduced, and a preliminary concept for LAB automation is described. Problems and unresolved issues are also addressed. Author

A89-18136#
TELEROBOTICS (SUPERVISED AUTONOMY) FOR SPACE APPLICATIONS
W. S. OTAGURO, L. O. KESLER, and D. D. BEEBE (McDonnell Douglas Astronautics Co., Huntington Beach, CA) IN: AIAA/IEEE Digital Avionics Systems Conference, 8th, San Jose, CA, Oct. 17-20, 1988, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 580-584.
(AIAA PAPER 88-3970)

This paper describes a telerobotic implementation as applied to autonomous guidance and control of platforms such as the Manned Maneuvering Unit (MMU), and mechanisms such as the Remote Manipulator System (RMS) using developed imaging tracker technology. With space qualified hardware such as the MMU and RMS which use cameras to monitor its operation under man's control, the approach adopted by MDAC used a developed imaging tracker system with enhanced positioning algorithms to provide the autonomous guidance and control of platforms and mechanisms. The modification of this imaging tracker into a robotic controller is presented. Its application to NASA's Extra-Vehicular Activity (EVA) retriever development and telerobotic operation is described. Author

A89-18329#
ARTIFICIAL INTELLIGENCE APPLICATION TO SPACE LOGISTICS
DAVID G. WINCHELL and JOHN B. CORCORAN (Perkin-Elmer Corp., Norwalk, CT) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 5 p.
(AIAA PAPER 88-4754)

A consensus has emerged that without AI's application, fully adequate Space Station telerobotics and robotic-servicing tasks will not be possible. Additional essential roles are presently foreseen for AI in the planning of space logistics missions, fault diagnosis with built-in test features, and expert knowledge retention and access. All such AI applications are facilitated by the availability of powerful, comparatively cheap computational resources; they are made imperative by the complexity of prospective orbiting systems such as the NASA Space Station. O.C.

A89-19551
AEROSPACE SIMULATION III; PROCEEDINGS OF THE SCS MULTICONFERENCE, SAN DIEGO, CA, FEB. 3-5, 1988
MONTE UNG, ED. (Southern California, University, Los Angeles, CA) Conference sponsored by the Society for Computer Simulation International. San Diego, CA, Society for Computer Simulation International (Simulation Series. Volume 19, No. 2, Apr. 1988), 1988, 316 p. For individual items see A89-19552 to A89-19573.

The conference presents papers on hardware-in-the-loop, aircrafts and rotorcrafts, missile applications, space applications, SDI, and research and developments. Particular attention is given to scene generation for real-time missile flight test, imaging missile simulations, and X-29 validation methodology for simulation and flight control system. Other topics include real-time simulation of the Space Station mobile service center, a model of the earth's magnetic field as applied to missile attitude reference, and AHIS-detailed endoatmospheric endgame digital simulation. K.K.

A89-19566* Lockheed Engineering and Management Services Co., Inc., Houston, TX.
REAL-TIME SIMULATION OF THE SPACE STATION MOBILE SERVICE CENTER
SEGUN THOMAS (Lockheed Engineering and Management Services Co., Inc., Houston, TX) IN: Aerospace simulation III; Proceedings of the SCS Multiconference, San Diego, CA, Feb. 3-5, 1988. San Diego, CA, Society for Computer Simulation International, 1988, p. 209-228. refs
(Contract NAS9-17900)

A method for building a generic N-joint simulation program is presented. It is shown that the multibody program can be operated in real time using a careful connection-array numbering scheme and a preprocessor. An example of a rigid manipulator on the Shuttle Orbiter was used to demonstrate the implementation technique. K.K.

A89-20110*# National Aeronautics and Space Administration, Washington, DC.
TELESCIENCE IN THE SPACE STATION ERA
E. R. SCHMERLING (NASA, Washington, DC) IN: EASCON '88; Proceedings of the Twenty-first Annual Electronics and Aerospace Conference, Arlington, VA, Nov. 9-11, 1988. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 87-91.

Telescience refers to the development of systems where participants involved in research in space can access their fellow scientists and the appropriate NASA services before flight, during flight, and after flight, preferably from their home institutions and through the same equipment. Telescience requires integration of available technologies to develop computer environments that maintain interoperability across different disciplines and different portions of the lifetimes of space experiments, called teledesign, teleoperations, and teleanalysis. Participants in the NASA Telescience Testbed Program are using a rigid prototyping approach to evaluate the necessary technologies and select the options and tradeoffs that best suit their accustomed modalities. The concept of transaction management is described, where the emphasis is placed on the effects of commands, whether event-generated onboard the spacecraft or sent up from the ground. Interoperability, security, and privacy issues are also discussed, and the Telescience Testbed Pilot Program is described. I.E.

A89-20112*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
THE FLIGHT TELEROBOTIC SERVICER PROJECT AND SYSTEMS OVERVIEW
HARRY G. MCCAIN and JAMES F. ANDARY (NASA, Goddard

Space Flight Center, Greenbelt, MD) IN: EASCON '88; Proceedings of the Twenty-first Annual Electronics and Aerospace Conference, Arlington, VA, Nov. 9-11, 1988. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 97-102. refs

As part of the Flight Telerobotic Servicer (FTS) project an advanced telerobotic system is being developed to assist in and reduce crew extravehicular activity (EVA) for the U.S. Space Station. The FTS will be used for assembly, maintenance, servicing, and inspection throughout the lifetime of the Space Station. A brief overview of the FTS program is given, and some of the technical and system engineering issues associated with the development of the FTS are explored. A key to the evolutionary capability of the FTS design is the NASREM (NASA Standard Reference Model for telerobot control system) architecture. This architecture provides the framework for future growth and permits a logical blend of teleoperation and autonomous operations as required. I.E.

A89-20113* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
GROUND OPERATION OF SPACE-BASED TELEROBOTS WILL ENHANCE PRODUCTIVITY
WAYNE R. SCHOBER (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: EASCON '88; Proceedings of the Twenty-first Annual Electronics and Aerospace Conference, Arlington, VA, Nov. 9-11, 1988. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 103-105. refs

Due to the limited human resources which will be available on the U.S. Space Station, automation and robotics technologies are being developed to enhance the productivity on the Space Station. The need for space telerobots which can be operated from the ground is explored, taking into consideration the resulting time delay, the technology involved, and some currently planned experiments. The proposed experiments include a remote link with the Kennedy Space Center robotics laboratory and the Telerobot Intelligent Interface Flight Experiment (TRIIFEX). It is concluded that there is a need to develop and implement ground-remote telerobotics technology which can effectively operate in the time-delay environment. This capability will enable servicing operations in polar and geosynchronous orbits and assist EVA astronauts on the Space Station. I.E.

A89-20602* North Carolina Univ., Charlotte.
USE OF CAD SYSTEMS IN DESIGN OF SPACE STATION AND SPACE ROBOTS
SUREN N. DWIVEDI, P. YADAV (North Carolina, University, Charlotte), GARY JONES, and ELMER W. TRAVIS (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Robotics and factories of the future '87; Proceedings of the Second International Conference, San Diego, CA, July 28-31, 1987. Berlin and New York, Springer-Verlag, 1988, p. 167-183. refs

The evolution of CAD systems is traced. State-of-the-art CAD systems are reviewed and various advanced CAD facilities and supplementing systems being used at NASA-Goddard are described. CAD hardware, computer software, and protocols are detailed. K.K.

A89-20651*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
THE FLIGHT TELEROBOTIC SERVICER PROGRAM
JOHN W. TOWNSEND, JR., JOHN E. OBERRIGHT (NASA, Goddard Space Flight Center, Greenbelt, MD), and JAMES S. ALBUS (NIST, Washington, DC) AIAA and NASA, International Symposium on Space Automation and Robotics, 1st, Arlington, VA, Nov. 29, 30, 1988. 5 p. refs
(AIAA PAPER 88-5001)

The Flight Telerobotic Servicer (FTS) Program, initiated by NASA to provide new capabilities for task accomplishment in the space environment, is described. The FTS Program includes the following: a series of test flights, a ground-based supporting infrastructure, and a technology utilization and transfer process. The FTS Program strives to reduce Space Station dependence on crew EVA, improve crew safety, enhance crew utilization, provide remote servicing capabilities for platforms, and accelerate technology transfer from research to U.S. industry. K.K.

A89-20652#
TELESCIENCE
L. YOUNG (MIT, Cambridge, MA) and B. LEINER (Research Institute for Advanced Computer Science, Moffett Field, CA) AIAA and NASA, International Symposium on Space Automation and Robotics, 1st, Arlington, VA, Nov. 29, 30, 1988. 8 p. refs
(AIAA PAPER 88-5002)

Telescience is the approach and collection of tools that enable productive scientific activity to be carried out using remote resources. By using interactive high-performance telecommunication links between space-based laboratories and facilities, on-orbit crew, and geographically dispersed ground-based investigator groups, facilities such as Space Station become an accessible and integral part of the research environment. In this paper, we describe an innovative program of rapid prototyping testbeds aimed at evaluating and validating telescience modes of operation and the technologies to support them. Particular attention is given to three testbeds evaluating remote instrumentation monitoring and control, expert systems in support of the interaction between the principal investigator and the astronaut, and telerobotics in support of fluid handling. In all of the testbeds, the application of these new technologies have been shown to improve scientific productivity. Author

A89-20653#
SPACE ROBOT FOR JAPAN'S ORBIT
YOJI UMETANI (Tokyo Institute of Technology, Japan) AIAA and NASA, International Symposium on Space Automation and Robotics, 1st, Arlington, VA, Nov. 29, 30, 1988. 3 p.
(AIAA PAPER 88-5003)

The basic policy for the development of space robots is discussed from the point of view of civilian space utlization of LEO. Technological problems are discussed and a definition of the stage and scenario is provided. Proposals are presented which include the Cosmo-lab project, earth-orbiting platform construction by the robot, and test facility construction for the robot. K.K.

A89-20654#
THE SPECIAL PURPOSE DEXTEROUS MANIPULATOR (SPDM) - A CANADIAN FOCUS FOR AUTOMATION AND ROBOTICS ON THE SPACE STATION
RICHARD C. HUGHES and DAVID G. HUNTER (National Research Council of Canada, Ottawa) AIAA and NASA, International Symposium on Space Automation and Robotics, 1st, Arlington, VA, Nov. 29, 30, 1988. 8 p.
(AIAA PAPER 88-5004)

The development of the Special Purpose Dexterous Manipulator (SPDM) as part of the Mobile Servicing System for the Space Station is examined. The SPDM is a robot with two arms, an articulated body, and sophisticated vision, force sensing, and control systems. The robot operates in both teleoperated and semiautonomous modes. The functional requirements for assembly, restoration, consumable replenishment, temporary storage, and transportation support are presented. The program to develop technologies to meet these requirements is discussed. R.B.

A89-20655#
SPACE ROBOTICS IN JAPAN
MASAMI IKEUCHI (National Space Development Agency of Japan, Tokyo) AIAA and NASA, International Symposium on Space Automation and Robotics, 1st, Arlington, VA, Nov. 29, 30, 1988. 7 p.
(AIAA PAPER 88-5005)

The current R & D status of Japanese Space Robotics and related activities is reviewed. The Japanese Experiment Module/Remote Manipulator System is described with attention given to the control mode and ground simulation. Research being conducted by NASDA on an advanced space robot to meet EVA

requirements is described. A development scenario of the operational platforms and the servicing vehicles is presented. K.K.

A89-20656#
AIR FORCE SPACE AUTOMATION AND ROBOTICS - AN ARTIFICIAL INTELLIGENCE ASSESSMENT
THOMAS R. FERGUSON and MARK A. GERSH (USAF, Systems Command, Andrews AFB, MD) AIAA and NASA, International Symposium on Space Automation and Robotics, 1st, Arlington, VA, Nov. 29, 30, 1988. 7 p.
(AIAA PAPER 88-5006)

Space applications requiring automation and robotics technology are discussed. The relationship between the Air Force and NASA is used to demonstrate the value of joint cooperation. Topics include mission requirements, technology challenges, Air Force initiatives, and future directions. K.K.

A89-20660*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SPACE TELEROBOTS AND PLANETARY ROVERS
CARL F. RUOFF (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) AIAA and NASA, International Symposium on Space Automation and Robotics, 1st, Arlington, VA, Nov. 29, 30, 1988. 21 p. refs
(AIAA PAPER 88-5011)

Space telerobots and planetary rovers are advanced forms of space automation that are being studied for missions beginning in the 1990s. This paper describes telerobots and planetary rovers, points out that pure autonomy is far beyond the state of the art, and goes on to discuss how useful, realizable telerobots and rovers can be developed in the context of human-machine systems. Telerobot and rover computational and architectural requirements are also briefly examined, and examples of current work, including the development of dedicated analog processing chips based upon neural networks are described. The paper closes with some speculations on the terrestrial implications of space robotics and some general conclusions. Author

A89-20835* Massachusetts Inst. of Tech., Cambridge.
MINIMIZATION OF SPACECRAFT DISTURBANCES IN SPACE-ROBOTIC SYSTEMS
ZIA VAFA and STEVEN DUBOWSKY (MIT, Cambridge, MA) IN: Guidance and control 1988; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 30-Feb. 3, 1988. San Diego, CA, Univelt, Inc., 1988, p. 91-108. refs
(Contract NAG1-489; NAG1-801)
(AAS PAPER 88-006)

Virtual manipulators for an arbitrary point of a real open chain space manipulator are presented. These virtual manipulators can be used to generate a disturbance map which can be used to select paths that reduce spacecraft disturbances. The present technique is applied to a simple two-link manipulator mounted on a free-floating spacecraft. K.K.

A89-21177* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
NASA RESEARCH AND DEVELOPMENT FOR SPACE TELEROBOTICS
PAUL S. SCHENKER (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) (California Institute of Technology, Workshop on Space Telerobotics, Pasadena, Jan. 1987) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 24, Sept. 1988, p. 523-534. refs

The goal of this research is to explore and prove out robust concepts for telerobotic support of space servicing, assembly, maintenance, and telescience tasks. This goal is being addressed through a program of coordinated work in artificial intelligence, robotics, and human factors. The general research objective is the fusion of robot sensing and manipulation, teleoperation, and human and machine cognitive skills into an effective architecture for supervised task automation. NASA is evaluating results of this research program in a ground laboratory telerobot testbed under development at JPL. The testbed development activity includes integrated technology demonstrations. The demonstrations will show telerobot capabilities to perform tasks of increasing complexity, and duration in increasingly unstructured environments. The first such demonstration is the ground-based grappling, dockling, and servicing of a satellite taskboard. I.E.

A89-21179* California Univ., Berkeley.
TELEROBOTICS - PROBLEMS AND RESEARCH NEEDS
LAWRENCE STARK, FRANK TENDICK, WON SOO KIM, RUSSELL ANDERSON, MICHAEL HISEY (California, University, Berkeley) et al. (California Institute of Technology, Workshop on Space Telerobotics, Pasadena, Jan. 1987) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 24, Sept. 1988, p. 542-551. Research supported by NASA. refs

With major emphasis on simulation, a university laboratory telerobotics facility permits problems to be approached by groups of graduate students. Helmet-mounded displays provide realism; the slaving of the display to the human operator's viewpoint gives a sense of 'telepresence' that may be useful for prolonged tasks. Using top-down three-dimensional model control of distant images allows distant images to be reduced to a few parameters to update the model used for display to the human operator in a preview mode to circumvent, in part, the communication delay. Also, the model can be used as a format for supervisory control and permit short-term local autonomous operations. Image processing algorithms can be made simpler and faster without trying to construct sensible images from the bottom. Control studies of telerobots lead to preferential manual control modes and basic paradigms for human motion and thence, perhaps, to redesign of robotic control, trajectory path planning, and rehabilitation prosthetics. I.E.

A89-21187
TASK PLANNING FOR ROBOTIC MANIPULATION IN SPACE APPLICATIONS
A. C. SANDERSON, M. A. PESHKIN, and L. S. HOMEM DE MELLO (Carnegie-Mellon University, Pittsburgh, PA) (California Institute of Technology, Workshop on Space Telerobotics, Pasadena, Jan. 1987) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251), vol. 24, Sept. 1988, p. 619-629. refs

Space-based robotic systems will require novel technologies of planning and manipulation to accomplish complex tasks such as diagnosis, repair, and assembly. This paper reviews recent results on task representation, discrete task planning, and control synthesis which provide a design environment for assembly systems, and which extend to the planning of manipulation operations in unstructured environments. In this approach, assembly planning is carried out using the AND/OR graph representation which encompasses all possible partial orders of operations and may be used to plan assembly sequences. A novel algorithm for planning disassembly and repair using the AND/OR graph is introduced, and examples of repair sequences generated for a satellite electrical module are described. For discrete task planning, the configuration map facilitates search over discrete parameters in the space of bounded configuration sets. I.E.

A89-22172* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
INTELLIGENT, AUTONOMOUS SYSTEMS IN SPACE
H. LUM and E. HEER (NASA, Ames Research Center, Moffett Field, CA) Acta Astronautica (ISSN 0094-5765), vol. 17, Oct. 1988, p. 1081-1091. refs

The Space Station is expected to be equipped with intelligent, autonomous capabilities; to achieve and incorporate these capabilities, the required technologies need to be identitifed, developed and validated within realistic application scenarios. The critical technologies for the development of intelligent, autonomous systems are discussed in the context of a generalized functional architecture. The present state of this technology implies that it be introduced and applied in an evolutionary process which must

start during the Space Station design phase. An approach is proposed to accomplish design information acquisition and management for knowledge-base development. Author

A89-23537* Texas A&M Univ., College Station.
DISPARITY CODING - AN APPROACH FOR STEREO RECONSTRUCTION
N. C. GRISWOLD and W. B. BELL (Texas A & M University, College Station) IN: Digital and optical shape representation and pattern recognition; Proceedings of the Meeting, Orlando, FL, Apr. 4-6, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 109-119.
(Contract NAG9-192)

As the possibility of stereo-controlled robots becomes a reality, the need to transmit the stereo pair of images to a ground station or space station for man-in-the-loop supervision will be a necessity. The complexity of transmitting stereo images by coding the preprocessed disparity is presently discussed. The approach demonstrates the quantization, modulation, and reconstruction of the stereo images. Results indicate the accuracy of reconstruction in terms of mean-square-error criterion as a function of the signal-to-noise ratio. Key research issues of interpolation from sparse disparity maps and reconstruction of the stereo pairs in the presence of spatial noise are presented. It is concluded that stereo reconstruction is possible, and the noise constraints are given. Author

A89-27605
THE ISA EXPERT SYSTEM - A PROTOTYPE SYSTEM FOR FAILURE DIAGNOSIS ON THE SPACE STATION
CHRISTOPHER A. MARSH (Mitre Corp., Houston, TX) IN: International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, 1st, Tullahoma, TN, June 1-3, 1988, Proceedings. Volume 1. Tullahoma, TN, University of Tennessee, 1988, p. 60-74. refs

The Operations Management System (OMS) is being designed to automate many aspects of flight control for the Space Station onboard systems. Ways in which the Integrated Status Assessment (ISA) expert system prototype is being used to help define the OMS are discussed. The ISA prototype expert system consists of a knowledge base, an inference engine, and a user interface. It was designed as a hybrid expert system using object-oriented programming, rule-based programming using both shallow and deep reasoning, and qualitative modeling. K.K.

A89-27615* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
ARTIFICIAL INTELLIGENCE APPROACHES IN SPACE POWER SYSTEMS AUTOMATION AT MARSHALL SPACE FLIGHT CENTER
DAVID J. WEEKS (NASA, Marshall Space Flight Center, Huntsville, AL) IN: International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems, 1st, Tullahoma, TN, June 1-3, 1988, Proceedings. Volume 1. Tullahoma, TN, University of Tennessee, 1988, p. 361-366. refs

Various applications of AI to spacecraft electrical power systems are described. Particular attention is given to NICBES (nickel-cadmium battery expert system which is interfaced with the Hubble Space Telescope electrical power system test bed); the SSES; the three cooperating AI systems in the Space Station module power management and distribution system test bed; and I-DARE, the intelligent data reduction expert. It is found that the utilization of AI approaches permits comprehensive fault management and dynamic rescheduling capabilities for the electrical power system. K.K.

A89-28438*# Teledyne Brown Engineering, Huntsville, AL.
THE IMPACT OF AN IVA ROBOT ON THE SPACE STATION MICROGRAVITY ENVIRONMENT
PHILLIP E. HARMAN (Teledyne Brown Engineering, Huntsville, AL) and DOUGLAS A. ROHN (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 14 p. refs
(Contract NAS3-25278)
(AIAA PAPER 89-0596)

In order to maintain a microgravity environment during Space Station operations, it will be necessary to minimize reaction forces. These mechanical forces will typically occur during reboost, docking, equipment operation, intravehicular activities (IVA) robot operation, or crew activity. This paper focuses on those disturbances created by an IVA robot and its impact on the Space Station microgravity environment. The robot dynamic analysis that was used to generate the forcing function as the input into a finite element model of the U.S. Laboratory will be shown. Acceleration levels were determined through analysis and have shown that a robotic system can sustain reaction forces into the station below 0.0001 g. A comparison between IVA robot effects and crew motion effects on the low-g environment is also described. It is concluded that robot trajectory shaping and motor accelerations feedback can minimize reaction forces. Author

A89-28439*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
GROUND-BASED SIMULATION OF TELEPRESENCE FOR MATERIALS SCIENCE EXPERIMENTS
JAMES C. JOHNSTON, BRUCE N. ROSENTHAL, MARY JO BONNER (NASA, Lewis Research Center, Cleveland, OH), RICHARD C. HAHN, and BRUCE HERBACH (Rensselaer Polytechnic Institute, Troy, NY) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p.
(AIAA PAPER 89-0597)

A series of ground-based telepresence experiments have been performed to determine the minimum video frame rate and resolution required for the successive performance of materials science experiments in space. The approach used is to simulate transmission between earth and space station with transmission between laboratories on earth. The experiments include isothermal dendrite growth, physical vapor transport, and glass melting. Modifications of existing apparatus, software developed, and the establishment of an inhouse network are reviewed. A.A.F.

A89-28628
PERFORMANCE IN ADAPTIVE MANIPULATOR CONTROL
GUNTER NIEMEYER and JEAN-JACQUES E. SLOTINE (MIT, Cambridge, MA) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1585-1591. Research supported by the Perry Foundation. refs
(Contract NSF MSM-88-03767; N00014-86-K-0685; N00015-85-K-0214)

The authors explore the performance issues linked to the effective implementation of adaptive manipulator controllers. Specifically, they detail issues of computational efficiency and recursive implementation, the treatment of closed chains, and minimal parameterizations. The authors also discuss extensions to interactions with mobile environments, whole-arm adaptive manipulation, adaptive impedance control, and adaptive control of spacecraft and space manipulators. The development is illustrated experimentally on a four-degree-of-freedom articulated robot arm, and suggests that the range of application of adaptive tracking controllers may extend well beyond adaptation to grasped loads. I.E.

A89-30652*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ADAPTIVE STRUCTURES
BEN K. WADA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 1. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1-11. refs
(AIAA PAPER 89-1160)

The fundamental principles of the adaptive structures concept

and its applications to current and planned space missions are reviewed and illustrated with diagrams, drawings, graphs, and photographs. An adaptive structure is defined as one which can be modified to meet mission requirements, either by remote commands or automatically in response to external stimuli. Topics addressed include the need for adaptive structures, analytical models, ground testing, sensor/actuator-structure interactions, structural concepts, active damping, wave propagation in large structures, the selection of active member locations, and on-orbit system identification. Particular attention is given to adaptive structures being developed for the NASA Large Deployable Reflector and Optical Interferometer projects. T.K.

A89-30768*# Duke Univ., Durham, NC.
CONTROL OF A SLOW MOVING SPACE CRANE AS AN ADAPTIVE STRUCTURE
S. UTKU, A. V. RAMESH, S. K. DAS (Duke University, Durham, NC), B. K. WADA, and G. S. CHEN (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1119-1126. refs
(AIAA PAPER 89-1286)

Assuming that the space crane is an adaptive structure with length-adjustable bars and taking as controls the length-adjustments of these bars, the computation of the incremental controls corresponding to the motion of a payload along its minimum-energy trajectory is given in terms of the inverse-transpose of matrix B of the joint equilibrium equations Bs = p, where s lists the bar forces and p lists the nodal loads. The compensation of the controls for elastic deformations and support movements are shown. It is also shown that the computations may be done automatically and in real time by an attached processor once the characteristics of the crane's maneuver are keyed in. Author

A89-30771#
AN ATTEMPT TO INTRODUCE INTELLIGENCE IN STRUCTURES
KORYO MIURA (Tokyo, University, Kanagawa, Japan) and SABURO MATUNAGA IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 3. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1145-1153. refs
(AIAA PAPER 89-1289)

The potential of intelligent structure is explored by studying a specific scenario whereby a large structure is constructed by assembling free-flying linear multilink intelligent structures using a robot. The intelligence of the structures includes: the ability to change their configuration arbitrarily and the ability of sensing their own geometry; the robot provides information on the external geometry of the structures and the power to operate the structures. Some problems arising with the use of intelligent structures and their possible solutions are briefly discussed. V.L.

A89-31076* Heer Associates, Inc., LaCanada, CA.
MACHINE INTELLIGENCE AND AUTONOMY FOR AEROSPACE SYSTEMS
EWALD HEER, ED. (Heer Associates, Inc., La Canada, CA) and HENRY LUM, ED. (NASA, Ames Research Center, Moffett Field, CA) Washington, DC, American Institute of Aeronautics and Astronautics, Inc. (Progress in Astronautics and Aeronautics. Volume 115), 1988, 369 p. For individual items see A89-31077 to A89-31091.

The present volume discusses progress toward intelligent robot systems in aerospace applications, NASA Space Program automation and robotics efforts, the supervisory control of telerobotics in space, machine intelligence and crew/vehicle interfaces, expert-system terms and building tools, and knowledge-acquisition for autonomous systems. Also discussed are methods for validation of knowledge-based systems, a design methodology for knowledge-based management systems, knowledge-based simulation for aerospace systems, knowledge-based diagnosis, planning and scheduling methods in AI, the treatment of uncertainty in AI, vision-sensing techniques in aerospace applications, image-understanding techniques, tactile sensing for robots, distributed sensor integration, and the control of articulated and deformable space structures. O.C.

A89-31077*# Heer Associates, Inc., LaCanada, CA.
TOWARD INTELLIGENT ROBOT SYSTEMS IN AEROSPACE
EWALD HEER (Heer Associates, Inc., La Canada, CA) and HENRY LUM (NASA, Ames Research Center, Moffett Field, CA) IN: Machine intelligence and autonomy for aerospace systems. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 1-13. refs

The incorporation of progressively more autonomous capabilities in spacecraft has been made possible by advancements in electronics technologies for sensors, communication, and computing equipment; as a result, space missions have been able to cope with ever-increasing complexity and data throughputs, as demonstrated by the six-order-of-magnitude increase in planetary mission data rates. In order to continue this pace of development into the Space Station era, NASA has accelerated its R&D in automation and robotics, with emphasis on autonomous, knowledge-based and expert system-employing technologies and AI. O.C.

A89-31078#
MANDATE FOR AUTOMATION AND ROBOTICS IN THE SPACE PROGRAM
DAVID R. CRISWELL (Universities Space Research Association, La Jolla, CA) IN: Machine intelligence and autonomy for aerospace systems. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 15-30. refs

The U.S. Congress has been so concerned about the role of automation and robotics (A&R) technologies in the NASA Space Station that NASA's Advanced Technology Advisory Committee has been directed to report on progress made on the implementation of its 13-point April 1, 1985 recommendations. One NASA objective pursuant to this A&R development thrust has been the enhancement of personnel and procedures' sophistication on A&R-related matters to the point where only the most dynamically technology-driving design requirements for the Space Station will be countenanced. Attention has also been given to prospective A&R technology spinoffs in the rest of the U.S. economy. Author

A89-31609* Lockheed Engineering and Sciences Co., Houston, TX.
GUIDELINES FOR THE USE OF PROGRAMMABLE DISPLAY PUSHBUTTONS ON THE SPACE STATION'S TELEROBOT CONTROL PANEL
MARK A. STUART, RANDY L. SMITH, and ERVETTE P. MOORE (Lockheed Engineering and Sciences Co., Houston, TX) IN: Human Factors Society, Annual Meeting, 32nd, Anaheim, CA, Oct. 24-28, 1988, Proceedings. Volume 1. Santa Monica, CA, Human Factors Society, 1988, p. 44-48.
(Contract NAS9-17900)

Simulations of a Remote Manipulator System task on microcomputer prototypes were performed to establish guidelines for using programmable display pushbuttons (PDP) on a telerobot control panel. Simulations of control panels with and without PDP were conducted. It is shown that there is a statistically significant increase in the number of commands issued in the non-PDP control panel. Guidelines for using PDP panels are listed. R.B.

N89-10063*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
PROCEEDINGS OF 1987 GODDARD CONFERENCE ON SPACE APPLICATIONS OF ARTIFICIAL INTELLIGENCE (AI) AND ROBOTICS
ELLEN G. STOLARIK, ed., RONALD G. LITTLEFIELD, ed., and DAVID S. BEYER, ed. 1987 718 p Conference held in

Greenbelt, Md., 13-14 May 1987
(NASA-TM-89663; NAS 1.15:89663) Avail: NTIS HC A99/MF E03 CSCL 22A

Topics addressed include: planning/scheduling expert systems; fault isolation/diagnosis expert systems; data processing/analysis expert systems; expert system tools/techniques; and robotics.

N89-10087*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SPACE TRUSS ASSEMBLY USING TELEOPERATED MANIPULATORS
WALTER W. HANKINS, III, RANDOLPH W. MIXON, HOWARD C. JONES, and THOMAS W. BURGESS (Oak Ridge National Lab., Tenn.) *In* NASA, Goddard Space Flight Center, Proceedings of 1987 Goddard Conference on Space Applications of Artificial Intelligence (AI) and Robotics 18 p 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

Teleoperator experiments were conducted which have demonstrated that a realistic, complex task, typical of those accomplished on-orbit by EVA astronauts, can be done in a smooth, timely manner with manipulators remotely controlled by humans. The real concerns were: (1) do manipulators have sufficient dexterity for these tasks, (2) can sufficient information from the remote site be provided to permit adequate teleoperator control, (3) can reasonable times relative to EVA times be achieved, (4) can the task be completed without frequent and/or damaging impacts among the task components and the manipulators? Positive answers were found to all of these concerns. Tasks times, operator fatigue, and smoothness of operation could be improved by designing the task components and the manipulators for greater compatibility. The data recorded supplements a data base of performance metrics for the same task done in the water immersion training facility as well as space flight and provides management with an objective basis for deciding how and where to apply manipulators in space. Author

N89-10089*# Grumman Aerospace Corp., Bethpage, NY.
OPEN CONTROL/DISPLAY SYSTEM FOR A TELEROBOTICS WORK STATION
SAUL KESLOWITZ *In* NASA, Goddard Space Flight Center, Proceedings of 1987 Goddard Conference on Space Applications of Artificial Intelligence (AI) and Robotics 21 p 1987
Avail: NTIS HC A99/MF E03 CSCL 05H

A working Advanced Space Cockpit was developed that integrated advanced control and display devices into a state-of-the-art multimicroprocessor hardware configuration, using window graphics and running under an object-oriented, multitasking real-time operating system environment. This Open Control/Display System supports the idea that the operator should be able to interactively monitor, select, control, and display information about many payloads aboard the Space Station using sets of I/O devices with a single, software-reconfigurable workstation. This is done while maintaining system consistency, yet the system is completely open to accept new additions and advances in hardware and software. The Advanced Space Cockpit, linked to Grumman's Hybrid Computing Facility and Large Amplitude Space Simulator (LASS), was used to test the Open Control/Display System via full-scale simulation of the following tasks: telerobotic truss assembly, RCS and thermal bus servicing, CMG changeout, RMS constrained motion and space constructible radiator assembly, HPA coordinated control, and OMV docking and tumbling satellite retrieval. The proposed man-machine interface standard discussed has evolved through many iterations of the tasks, and is based on feedback from NASA and Air Force personnel who performed those tasks in the LASS. Author

N89-10097*# Little (Arthur D.), Inc., Cambridge, MA.
ROBOT HANDS AND EXTRAVEHICULAR ACTIVITY
BETH MARCUS *In* NASA, Goddard Space Flight Center, Proceedings of 1987 Goddard Conference on Space Applications of Artificial Intelligence (AI) and Robotics 16 p 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

Extravehicular activity (EVA) is crucial to the success of both current and future space operations. As space operations have evolved in complexity so has the demand placed on the EVA crewman. In addition, some NASA requirements for human capabilities at remote or hazardous sites were identified. One of the keys to performing useful EVA tasks is the ability to manipulate objects accurately, quickly and without early or excessive fatigue. The current suit employs a glove which enables the crewman to perform grasping tasks, use tools, turn switches, and perform other tasks for short periods of time. However, the glove's bulk and resistance to motion ultimately causes fatigue. Due to this limitation it may not be possible to meet the productivity requirements that will be placed on the EVA crewman of the future with the current or developmental Extravehicular Mobility Unit (EMU) hardware. In addition, this hardware will not meet the requirements for remote or hazardous operations. In an effort to develop ways for improving crew productivity, a contract was awarded to develop a prototype anthromorphic robotic hand (ARH) for use with an extravehicular space suit. The first step in this program was to perform a a design study which investigated the basic technology required for the development of an ARH to enhance crew performance and productivity. The design study phase of the contract and some additional development work is summarized. Author

N89-10099*# National Bureau of Standards, Gaithersburg, MD. Robot Systems Div.
NASREN: STANDARD REFERENCE MODEL FOR TELEROBOT CONTROL
J. S. ALBUS, R. LUMIA, and H. MCCAIN *In* NASA, Goddard Space Flight Center, Proceedings of 1987 Goddard Conference on Space Applications of Artificial Intelligence (AI) and Robotics 19 p 1987
Avail: NTIS HC A99/MF E03 CSCL 09B

A hierarchical architecture is described which supports space station telerobots in a variety of modes. The system is divided into three hierarchies: task decomposition, world model, and sensory processing. Goals at each level of the task dedomposition heirarchy are divided both spatially and temporally into simpler commands for the next lower level. This decomposition is repreated until, at the lowest level, the drive signals to the robot actuators are generated. To accomplish its goals, task decomposition modules must often use information stored it the world model. The purpose of the sensory system is to update the world model as rapidly as possible to keep the model in registration with the physical world. The architecture of the entire control system hierarch is described and how it can be applied to space telerobot applications. Author

N89-10100*# RCA Astro-Electronics Div., Princeton, NJ. Space Div.
KINEMATIC STUDY OF FLIGHT TELEROBOTIC SERVICER CONFIGURATION ISSUES
R. H. LEWIS, R. D. SCOTT, and W. S. HOWARD *In* NASA, Goddard Space Flight Center, Proceedings of 1987 Goddard Conference on Space Applications of Artificial Intelligence (AI) and Robotics 17 p 1987
Avail: NTIS HC A99/MF E03 CSCL 22B

Several factors, such as body size and shape, and the number of arms and their placement, will influence how well the Flight Telerobotic Servicer (FTS) is suited to its potential duties for the Space Station Program. In order to examine the implications of these configuration options, eight specific 2, 3, and 4 armed FTS configuration were simulated and used to perform a Space Station Orbital Replacement Unit (ORU) exchange. The strengths and weaknesses of each configuration were evaluated. Although most of the configurations examined were able to perform the exchange, several of the 3 and 4 arm configurations had operational advantages. The results obtained form these simulations are specific to the assumptions associated with the ORU exchange scenario examined. However, they do illustrate the general interrelationships and sensitivities which need to be understood. Author

N89-11237*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SPACE-BASED MULTIFUNCTIONAL END EFFECTOR SYSTEMS FUNCTIONAL REQUIREMENTS AND PROPOSED DESIGNS
A. H. MISHKIN and B. M. JAU 15 Apr. 1988 119 p
(Contract NAS7-918)
(NASA-CR-180390; JPL-PUBL-88-16; NAS 1.26:180390) Avail: NTIS HC A06/MF A01 CSCL 13/9

The end effector is an essential element of teleoperator and telerobot systems to be employed in space in the next decade. The report defines functional requirements for end effector systems to perform operations that are currently only feasible through Extra-Vehicular Activity (EVA). Specific tasks and functions that the end effectors must be capable of performing are delineated. Required capabilities for forces and torques, clearances, compliance, and sensing are described, using current EVA requirements as guidelines where feasible. The implications of these functional requirements on the elements of potential end effector systems are discussed. The systems issues that must be considered in the design of space-based manipulator systems are identified; including impacts on subsystems tightly coupled to the end effector, i.e., control station, information processing, manipulator arm, tool and equipment stowage. Possible end effector designs are divided into three categories: single degree-of-freedom end effectors, multiple degree of freedom end effectors, and anthropomorphic hands. Specific design alternatives are suggested and analyzed within the individual categories. Two evaluations are performed: the first considers how well the individual end effectors could substitute for EVA; the second compares how manipulator systems composed of the top performers from the first evaluation would improve the space shuttle Remote Manipulator System (RMS) capabilities. The analysis concludes that the anthropomorphic hand is best-suited for EVA tasks. A left- and right-handed anthropomorphic manipulator arm configuration is suggested as appropriate to be affixed to the RMS, but could also be used as part of the Smart Front End for the Orbital Maneuvering Vehicle (OMV). The technical feasibility of the anthropomorphic hand and its control are demonstrated. An evolutionary development approach is proposed and approximate scheduling provided for implementing the suggested manipulator systems in time for space stations operations in the early 1990s. Author

N89-11773*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
SYSTEMS AUTONOMY
HENRY LUM, JR. *In* NASA, Washington, Technology for Future NASA Missions: Civil Space Technology Initiative (CSTI) and Pathfinder p 247-281 Sep. 1988
Avail: NTIS HC A23/MF A01 CSCL 22/1

Information on systems autonomy is given in viewgraph form. Information is given on space systems integration, intelligent autonomous systems, automated systems for in-flight mission operations, the Systems Autonomy Demonstration Project on the Space Station Thermal Control System, the architecture of an autonomous intelligent system, artificial intelligence research issues, machine learning, and real-time image processing. R.J.F.

N89-12065# MATRA Espace, Paris-Velizy (France).
SERVICE VISION SUBSYSTEM (SVS)
Paris, France ESA 8 Feb. 1988 19 p Original contains color illustrations
(Contract ESTEC-6495/85-NL-PB(SC))
(ESA-CR(P)-2643; ETN-88-93172) Avail: NTIS HC A03/MF A01

A service vision subsystem (SVS) for a spaceborne service manipulator (SMS) system was defined. The SVS functions are: proximity sensory function involving camera sensor and requiring image processing capabilities in order to deliver information requested by the control unit; and potential image preprocessing (compression) requested by the telemeasure and telecommand subsystem. The types of image processing are related to the operation to perform. For basic functions, SVS acts as a proximity sensor for the automatic control of the SMS, and as an imaging device (including image compression) for inspection. Extended functions include enhancement of the image, and feature extraction for improving the monitoring and teleoperation; and SVS as a 3-D sensor for less favorable conditions (unlit targets, nonmarked targets, etc.). The basic functions were studied and implemented on the SVS breadboard. The extended functions were studied, requirements analyzed, and algorithms simulated. ESA

N89-12199*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
STEREO DEPTH DISTORTIONS IN TELEOPERATION
DANIEL B. DINER and MARIKA VONSYDOW 15 May 1988 57 p
(Contract NAS7-918)
(NASA-CR-180242; JPL-PUB-87-1-REV-1; NAS 1.26:180242)
Avail: NTIS HC A04/MF A01 CSCL 05/8

In teleoperation, a typical application of stereo vision is to view a work space located short distances (1 to 3m) in front of the cameras. The work presented here treats converged camera placement and studies the effects of intercamera distance, camera-to-object viewing distance, and focal length of the camera lenses on both stereo depth resolution and stereo depth distortion. While viewing the fronto-parallel plane 1.4 m in front of the cameras, depth errors are measured on the order of 2cm. A geometric analysis was made of the distortion of the fronto-parallel plane of divergence for stereo TV viewing. The results of the analysis were then verified experimentally. The objective was to determine the optimal camera configuration which gave high stereo depth resolution while minimizing stereo depth distortion. It is found that for converged cameras at a fixed camera-to-object viewing distance, larger intercamera distances allow higher depth resolutions, but cause greater depth distortions. Thus with larger intercamera distances, operators will make greater depth errors (because of the greater distortions), but will be more certain that they are not errors (because of the higher resolution). Author

N89-12595*# Control Dynamics Co., Huntsville, AL.
THE FLIGHT ROBOTICS LABORATORY
PATRICK A. TOBBE, MARLIN J. WILLIAMSON, and JOHN R. GLAESE *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 158-167 1988
(Contract NAS8-36570)
Avail: NTIS HC A21/MF A01 CSCL 14/2

The Flight Robotics Laboratory of the Marshall Space Flight Center is described in detail. This facility, containing an eight degree of freedom manipulator, precision air bearing floor, teleoperated motion base, reconfigurable operator's console, and VAX 11/750 computer system, provides simulation capability to study human/system interactions of remote systems. The facility hardware, software and subsequent integration of these components into a real time man-in-the-loop simulation for the evaluation of spacecraft contact proximity and dynamics are described. Author

N89-12621* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SPACE STATION ERECTABLE MANIPULATOR PLACEMENT SYSTEM Patent
MARGARET E. GRIMALDI, inventor (to NASA) 20 Sep. 1988 7 p Filed 13 Nov. 1986 Supersedes N87-18596 (25 - 11, p 1446)
(NASA-CASE-MSC-21096-1; US-PATENT-4,772,175; US-PATENT-APPL-SN-929865; US-PATENT-CLASS-414-689; US-PATENT-CLASS-414-718; US-PATENT-CLASS-414-735; US-PATENT-CLASS-212-225; US-PATENT-CLASS-212-257; US-PATENT-CLASS-182-103) Avail: US Patent and Trademark Office CSCL 22/1

A habitable space station was proposed for low earth orbit, to be constructed from components which will be separately carried up from the earth and thereafter assembled. A suitable manipulating system having extraordinary manipulative capability is required. The

invention is an erectable manipulator placement system for use on a space station and comprises an elongate, lattice-like boom having guide tracks attached thereto, a carriage-like assembly pivotally mounted on and extending from said dolly. The system further includes a turntable base pivotally interconnected with the proximal end of the boom and positioned either on a part of a transferring vehicle, or on another payload component being carried by the said transferring vehicle, or on the space station. Novelty resides in the use of a turntable base having a hinged boom with a dolly translatable therealong to carry the arm-like assembly, thus providing an additional 3 degrees of freedom to the arm.
Official Gazette of the U.S. Patent and Trademark Office

N89-13198*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ADVANCING AUTOMATION AND ROBOTICS TECHNOLOGY FOR THE SPACE STATION AND FOR THE US ECONOMY Progress Report No. 6, Oct. 1987 - Mar. 1988
ROBERT NUNAMAKER 15 Jun. 1988 54 p Prepared in cooperation with NASA, Lyndon B. Johnson Space Center, Houston, Tex.
(NASA-TM-100989; NAS 1.15:100989) Avail: NTIS HC A04/MF A01 CSCL 09/2

In April 1985, as required by Public Law 98-371, the NASA Advanced Technology Advisory Committee (ATAC) reported to Congress the results of its studies on advanced automation and robotics technology for use on the Space Station. This material was documented in the initial report (NASA Technical Memo 87566). A further requirement of the law was that ATAC follow NASA's progress in this area and report to Congress semiannually. This report is the sixth in a series of progress updates and covers the period between October 1, 1987 and March 1, 1988. NASA has accepted the basic recommendations of ATAC for its Space Station efforts. ATAC and NASA agree that the thrust of Congress is to build an advanced automation and robotics technology base that will support an evolutionary Space Station program and serve as a highly visible stimulator affecting the U.S. long-term economy. The progress report identifies the work of NASA and the Space Station study contractors, research in progress, and issues connected with the advancement of automation and robotics technology on the Space Station. Author

N89-13487*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE VERSATILITY OF A TRUSS MOUNTED MOBILE TRANSPORTER FOR IN-SPACE CONSTRUCTION
HAROLD G. BUSH, MARK S. LAKE, JUDITH J. WATSON, and WALTER L. HEARD, JR. Nov. 1988 19 p
(NASA-TM-101514; NAS 1.15:101514) Avail: NTIS HC A03/MF A01 CSCL 22/2

The Mobile Transporter (MT) evolution from early erectable structures assembly activities is detailed. The MT operational features which are required to support astronauts performing on-orbit structure construction or spacecraft assembly functions are presented and discussed. Use of the MT to perform a variety of assembly functions is presented. Estimated EVA assembly times for a precision segmented reflector approximately 20 m in diameter are presented. The EVA/MT technique under study for construction of the reflector (and the entire spacecraft) is illustrated. Finally, the current status of development activities and test results involving the MT and Space Station structural assembly are presented. Author

N89-14156*# Iowa State Univ. of Science and Technology, Ames.
THREE DEGREE-OF-FREEDOM FORCE FEEDBACK CONTROL FOR ROBOTIC MATING OF UMBILICAL LINES
R. REES FULLMER *In* NASA, John F. Kennedy Space Center, NASA/ASEE Summer Faculty Fellowship Program: 1988 Research Reports p 19-41 Oct. 1988
Avail: NTIS HC A24/MF A01 CSCL 13/9

The use of robotic manipulators for the mating and demating of umbilical fuel lines to the Space Shuttle Vehicle prior to launch is investigated. Force feedback control is necessary to minimize the contact forces which develop during mating. The objective is to develop and demonstrate a working robotic force control system. Initial experimental force control tests with an ASEA IRB-90 industrial robot using the system's Adaptive Control capabilities indicated that control stability would by a primary problem. An investigation of the ASEA system showed a 0.280 second software delay between force input commands and the output of command voltages to the servo system. This computational delay was identified as the primary cause of the instability. Tests on a second path into the ASEA's control computer using the MicroVax II supervisory computer show that time delay would be comparable, offering no stability improvement. An alternative approach was developed where the digital control system of the robot was disconnected and an analog electronic force controller was used to control the robot's servosystem directly, allowing the robot to use force feedback control while in rigid contact with a moving three-degree-of-freedom target. An alternative approach was developed where the digital control system of the robot was disconnected and an analog electronic force controller was used to control the robot's servo system directly. This method allowed the robot to use force feedback control while in rigid contact with moving three degree-of-freedom target. Tests on this approach indicated adequate force feedback control even under worst case conditions. A strategy to digitally-controlled vision system was developed. This requires switching between the digital controller when using vision control and the analog controller when using force control, depending on whether or not the mating plates are in contact. Author

N89-14898*# Jackson State Univ., MS.MS. Dept. of Technology.
END-EFFECTOR - JOINT CONJUGATES FOR ROBOTIC ASSEMBLY OF LARGE TRUSS STRUCTURES IN SPACE: A SECOND GENERATION Abstract Only
W. V. BREWER *In* Hampton Inst., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988 p 38-43 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 22/2

Current designs, a first generation intended for robotic assembly, have given priority to the ease and certainty of the assembly process under less than ideal conditions with a minimum of sensory feedback. As a consequence they are either heavy or expensive and all exhibit a relatively low packaging density. Low packaging density is caused by extensive scars applied to the node, increasing its envelope diameter by as much as 150 percent. Strut envelopes are violated to a lessor extent with diameters increased by 25 percent or more. This smaller percentage is still a significant problem owing to a much higher fraction of the packaged volume represented by struts. As structures in space become larger, packaging density becomes an important consideration. The objective is to develop end-effector-joint conjugates that do not violate the envelopes of a 2.5 inch diameter node or a 1.0 inch diameter strut. Author

N89-15004*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
AN OVERVIEW OF THE PROGRAM TO PLACE ADVANCED AUTOMATION AND ROBOTICS ON THE SPACE STATION
RICHARD P. HEYDORN *In its* Experiments in Planetary and Related Sciences and the Space Station 6 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 22/2

The preliminary design phase of the Space Station has uncovered a large number of potential uses of automation and robotics, most of which deal with the assembly and operation of the Station. If NASA were to vigorously push automation and robotics concepts in the design, the Station crew would probably be free to spend a substantial portion of time on payload activities. However, at this point NASA has taken a conservative attitude toward automation and robotics. For example, the belief is that robotics should evolve through telerobotics and that uses of artificial intelligence should be initially used in an advisory capacity. This conservativeness is in part due to the new and untested nature

of automation and robotics; but, it is also due to emphases plased on designing the Station to the so-called upfront cost without thoroughly understanding the life cycle cost. Presumably automation and robotics has a tendency to increase the initial cost of the Space Station but could substantially reduce the life cycle cost. To insure that NASA will include some form of robotic capability, Congress directed to set aside funding. While this stimulates the development of robotics, it does not necessarily stimulate uses of artificial intelligence. However, since the initial development costs of some forms of artificial intelligence, such as expert systems, are in general lower than they are for robotics one is likely to see several expert systems being used on the Station. Author

N89-15410# National Aerospace Lab., Amsterdam (Netherlands). Space Div.
FLEXIBLE ROBOTIC MANIPULATOR IN SPACE: TOWARDS A MATHEMATICAL DYNAMICS TRUTH MODEL
P. TH. L. M. VANWOERKOM 15 Sep. 1987 49 p
(Contract NIVR-02506-N)
(NLR-TR-87129-U; ETN-89-93889) Avail: NTIS HC A03/MF A01

A mathematical truth model for the dynamics of a robotic manipulator which is attached to an orbiting spacecraft-manipulator system consisting of structurally flexible bodies is discussed. The dynamics equations for a single constituent body in the spacecraft-manipulator system are developed, using the method of hybrid coordinate modeling. The equations obtained are to form the basis for the development of the dynamics equations of the entire spacecraft manipulator system. ESA

N89-15591*# Arizona Univ., Tucson. Dept. of Electrical and Computer Engineering.
DESIGN OF A SIMULATION ENVIRONMENT FOR LABORATORY MANAGEMENT BY ROBOT ORGANIZATIONS
BERNARD P. ZEIGLER, FRANCOIS E. CELLIER, and JERZY W. ROZENBLIT *In* NASA, Marshall Space Flight Center, Fourth Conference on Artificial Intelligence for Space Applications p 313-321 Oct. 1988
(Contract NCC2-525)
Avail: NTIS HC A21/MF A01 CSCL 05/1

This paper describes the basic concepts needed for a simulation environment capable of supporting the design of robot organizations for managing chemical, or similar, laboratories on the planned U.S. Space Station. The environment should facilitate a thorough study of the problems to be encountered in assigning the responsibility of managing a non-life-critical, but mission valuable, process to an organized group of robots. In the first phase of the work, we seek to employ the simulation environment to develop robot cognitive systems and strategies for effective multi-robot management of chemical experiments. Later phases will explore human-robot interaction and development of robot autonomy. Author

N89-15599*# Rockwell International Corp., Downey, CA. SBI Software Engineering.
ARTIFICIAL INTELLIGENCE APPLICATIONS IN SPACE AND SDI: A SURVEY
HARVEY E. FIALA *In* NASA, Marshall Space Flight Center, Fourth Conference on Artificial Intelligence for Space Applications p 381-390 Oct. 1988
Avail: NTIS HC A21/MF A01 CSCL 09/2

The purpose of this paper is to survey existing and planned Artificial Intelligence (AI) applications to show that they are sufficiently advanced for 32 percent of all space applications and SDI (Space Defense Initiative) software to be AI-based software. To best define the needs that AI can fill in space and SDI programs, this paper enumerates primary areas of research and lists generic application areas. Current and planned NASA and military space projects in AI will be reviewed. This review will be largely in the selected area of expert systems. Finally, direct applications of AI to SDI will be treated. The conclusion covers the importance of AI to space and SDI applications, and conversely, their importance to AI. Author

N89-15610*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
CONSIDERATIONS IN DEVELOPMENT OF EXPERT SYSTEMS FOR REAL-TIME SPACE APPLICATIONS
S. MURUGESAN *In* NASA, Marshall Space Flight Center, Fourth Conference on Artificial Intelligence for Space Applications p 487-496 Oct. 1988
Avail: NTIS HC A21/MF A01 CSCL 05/1

Over the years, demand on space systems has increased tremendously and this trend will continue for the near future. Enhanced capabilities of space systems, however, can only be met with increased complexity and sophistication of onboard and ground systems. Artificial Intelligence and expert system techniques have great potential in space applications. Expert systems could facilitate autonomous decision making, improve in-orbit fault diagnosis and repair, enhance performance and reduce reliance on ground support. However, real-time expert systems, unlike conventional off-line consultative systems, have to satisfy certain special stringent requirements before they could be used for onboard space applications. Challenging and interesting new environments are faced while developing expert system space applications. This paper discusses the special characteristics, requirements and typical life cycle issues for onboard expert systems. Further, it also describes considerations in design, development, and implementation which are particularly important to real-time expert systems for space applications. Author

N89-15649*# Alabama Univ., Huntsville. Research Center.
APPLICATIONS OF ARTIFICIAL INTELLIGENCE TO SPACE STATION: GENERAL PURPOSE INTELLIGENT SENSOR INTERFACE Final Report, 1987-1988
JAMES W. MCKEE Sep. 1988 86 p
(Contract NAG8-641)
(NASA-CR-184572; NAS 1.26:184572; UAH-RR-728) Avail: NTIS HC A05/MF A01 CSCL 09/2

This final report describes the accomplishments of the General Purpose Intelligent Senscr Interface task of the Applications of Artificial Intelligence to Space Station grant for the period from October 1, 1987 through September 30, 1988. Portions of the First Biannual Report not revised will not be included but only referenced. The goal is to develop an intelligent sensor system that will simplify the design and development of expert systems using sensors of the physical phenomena as a source of data. This research will concentrate on the integration of image processing sensors and voice processing sensors with a computer designed for expert system development. The result of this research will be the design and documentation of a system in which the user will not need to be an expert in such areas as image processing algorithms, local area networks, image processor hardware selection or interfacing, television camera selection, voice recognition hardware selection, or analog signal processing. The user will be able to access data from video or voice sensors through standard LISP statements without any need to know about the sensor hardware or software. Author

N89-17444*# Catholic Univ. of America, Washington, DC. Dept. of Electrical Engineering.
DEVELOPMENT OF KINEMATIC EQUATIONS AND DETERMINATION OF WORKSPACE OF A 6 DOF END-EFFECTOR WITH CLOSED-KINEMATIC CHAIN MECHANISM Interim Report, 1 Jul. 1988 - 1 Jan. 1989
CHARLES C. NGUYEN and FARHAD J. POORAN Feb. 1989 17 p
(Contract NAG5-780)
(NASA-CR-183241; NAS 1.26:183241) Avail: NTIS HC A03/MF A01 CSCL 12/1

This report presents results from the research grant entitled Active Control of Robot Manipulators, funded by the Goddard Space Flight Center, under Grant NAG5-780, for the period July 1, 1988 to January 1, 1989. An analysis is presented of a 6 degree-of-freedom robot end-effector built to study telerobotic assembly of NASA hardware in space. Since the end-effector is required to perform high precision motion in a limited workspace,

closed-kinematic mechanisms are chosen for its design. A closed-form solution is obtained for the inverse kinematic problem and an iterative procedure employing Newton-Raphson method is proposed to solve the forward kinematic problem. A study of the end-effector workspace results in a general procedure for the workspace determination based on link constraints. Computer simulation results are presented. Author

N89-18045*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
SYSTEMS AUTONOMY TECHNOLOGY: EXECUTIVE SUMMARY AND PROGRAM PLAN
JOHN S BULL, ed. Dec. 1987 167 p Prepared in cooperation with NASA. Goddard Space Flight Center, Greenbelt, MD; JPL, Calif., Inst. of Tech., Pasadena; Johnson Space Center; Kennedy Space Center; Langley Research Center; Lewis Research Center and Marshall Space Flight Center
(NASA-TM-100999; A-88174; NAS 1.15:100999) Avail: NTIS HC A08/MF A01 CSCL 09/2

The National Space Strategy approved by the President and Congress in 1984 sets for NASA a major goal of conducting effective and productive space applications and technology programs which contribute materially toward United States leadership and security. To contribute to this goal, OAST supports the Nation's civil and defense space programs and overall economic growth. OAST objectives are to ensure timely provision of new concepts and advanced technologies, to support both the development of NASA missions in space and the space activities of industry and other organizations, to utilize the strengths of universities in conducting the NASA space research and technology program, and to maintain the NASA centers in positions of strength in critical space technology areas. In line with these objectives, NASA has established a new program in space automation and robotics that will result in the development and transfer and automation technology to increase the capabilities, productivity, and safety of NASA space programs including the Space Station, automated space platforms, lunar bases, Mars missions, and other deep space ventures. The NASA/OAST Automation and Robotics program is divided into two parts. Ames Research Center has the lead role in developing and demonstrating System Autonomy capabilities for space systems that need to make their own decisions and do their own planning. The Jet Propulsion Laboratory has the lead role for Telerobotics (that portion of the program that has a strong human operator component in the control loop and some remote handling requirement in space). This program is intended to be a working document for NASA Headquarters, Program Offices, and implementing Project Management. Author

N89-18398*# National Aeronautics and Space Administration, Washington, DC.
AUTOMATION AND ROBOTICS
MELVIN MONTEMERLO *In its* NASA Information Sciences and Human Factors Program p 1-28 Sep. 1988
Avail: NTIS HC A10/MF A01 CSCL 13/9

The Autonomous Systems focus on the automation of control systems for the Space Station and mission operations. Telerobotics focuses on automation for in-space servicing, assembly, and repair. The Autonomous Systems and Telerobotics each have a planned sequence of integrated demonstrations showing the evolutionary advance of the state-of-the-art. Progress is briefly described for each area of concern. B.G.

N89-18599# MATRA Espace, Paris-Velizy (France).
TELESCIENCE SYSTEM CONCEPT STUDY. VOLUME 1: EXECUTIVE SUMMARY Final Report
Paris, France ESA Nov. 1987 50 p Prepared in cooperation with Messerschmitt-Boelkow-Bolhm/Entwichlungspring Nord, Bremen (Germany, F. R.)
(Contract ESTEC-6977/86-NL-PP(SC))
(MATRA-NT/2113/139-VOL-1; ESA-CR(P)-2592-VOL-1; ETN-89-93642) Avail: NTIS HC A03/MF A01

A demonstration test for Columbus interactive user operations is defined. The data management system (DMS) test bed and the crew work station (CWS) test bed represent the on-board facilities. A pilot experiment (PE), using the fluid physics module, is physically integrated into DMS/CWS test beds. The data management laboratory (DML), providing the necessary test environment, represents the ground segment and the space/ground links. A scientific user, interfaces the telescience test bed (TB) through a console of the DML. A payload on-board operator, interfaces the telescience test bed through CWS-TB facilities and has direct physical and visual contacts with the PE. Hardware and basic software configurations necessary to run the telescience demonstration tests are defined. ESA

N89-19478# MATRA Espace, Paris-Velizy (France).
TELESCIENCE SYSTEM CONCEPT STUDY, VOLUME 2 Final Report
Paris, France ESA Nov. 1987 291 p Prepared in cooperation with Messerschmitt-Boelkow-Blohm/Entwicklungspring Nord, Bremen (Federal Republic of Germany)
(Contract ESTEC-6977/86-NL-PP(SC))
(MATRA-NT/2113/139-VOL-2; ESA-CR(P)-2592-VOL-2; ETN-89-93643) Avail: NTIS HC A13/MF A01

A demonstration test for Columbus interactive user operations is defined. The data management system (DMS) test bed and the crew work station (CWS) test bed represent the on-board facilities. A pilot experiment (PE), using the fluid physics module, is physically integrated into DMS/CWS test beds. The data management laboratory (DML), providing the necessary test environment, represents the ground segment and the space/ground links. A scientific user, interfaces the telescience test bed (TB) through a console of the DML. A payload on-board operator, interfaces the telescience test bed through CWS-TB facilities and has direct physical and visual contact with the PE. Hardware and basic software configurations necessary to run the telescience demonstration tests are defined. ESA

N89-19575# Technische Univ., Delft (Netherlands).
A FINITE ELEMENT DYNAMIC ANALYSIS OF FLEXIBLE SPATIAL MECHANISMS AND MANIPULATORS Ph.D. Thesis
BEN JONKER 1988 162 p
(ETN-89-93901) Avail: NTIS HC A08/MF A01

A finite-element based method for the dynamic analysis of spatial mechanisms and manipulators with flexible links is presented. Finite element types, appropriate for modeling spatial mechanisms are presented. For each element, expressions for the deformation modes as analytical functions of the element nodal coordinates are defined. The angular orientations are described in terms of four Euler parameters; in contrast to Euler angles or any set of three angular generalized coordinates, these parameters display no singular behavior of the rotational transformations. The constraint condition for the Euler parameters can easily be incorporated in the theory as it is a condition similar to the constraint condition for undeformable finite elements. The kinematic description of multi degree of freedom mechanisms based on the geometric transfer function formalism is considered. The list of derivatives of the geometric transfer functions is extended up to the third order. The associated computation scheme for the kinematic analysis is described. The choice of the degrees of freedom is discussed. ESA

N89-19862*# CAMUS, Inc., Huntsville, AL.
MAN-SYSTEMS REQUIREMENTS FOR THE CONTROL OF TELEOPERATORS IN SPACE
NICHOLAS L. SHIELDS, JR. *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 329-334 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 05/8

The microgravity of the space environment has profound effects on humans and, consequently, on the design requirements for subsystems and components with which humans interact. There are changes in the anthropometry, vision, the perception of orientation, posture, and the ways in which we exert energy. The design requirements for proper human engineering must reflect each of the changes that results, and this is especially true in the

exercise of control over remote and teleoperated systems where the operator is removed from any direct sense of control. The National Aeronautics and Space Administration has recently completed the first NASA-wide human factors standard for microgravity. The Man-Systems Integration Standard, NASA-STD-3000, contains considerable information on the appropriate design criteria for microgravity, and there is information that is useful in the design for teleoperated systems. There is not, however, a dedicated collection of data which pertains directly to the special cases of remote and robotic operations. The design considerations for human-system interaction in the control of remote systems in space are discussed, with brief details on the information to be found in the NASA-STD-3000, and arguments for a dedicated section within the Standard which deals with robotic, teleoperated and remote systems and the design requirements for effective human control of these systems in the space environment, and from the space environment. Author

N89-19870*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
DESIGN CONCEPT FOR THE FLIGHT TELEROBOTIC SERVICER (FITS)
J. F. ANDARY, S. W. HINKAI, and J. G. WATZIN *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 391-396 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 05/8

NASA has just completed an in-house Phase B Study (one of three studies) for the preliminary definition of a teleoperated robotic device that will be used on the National Space Transportation System (NSTS) and the Space Station to assist the astronauts in the performance of assembly, maintenance, servicing, and inspection tasks. This device, the Flight Telerobotic Servicer (FTS), will become a permanent element on the Space Station. Although it is primarily a teleoperated device, the FTS is being designed to grow and evolve to higher states of autonomy. Eventually, it will be capable of working from the Orbital Maneuvering Vehicle (OMV) to service free-flying spacecraft at great distances from the Space Station. A version of the FTS could also be resident on the large space platforms that are part of the Space Station Program. Author

N89-19879*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
MACHINE VISION FOR SPACE TELEROBOTICS AND PLANETARY ROVERS
BRIAN H. WILCOX *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 457-460 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 05/8

Machine vision allows a non-contact means of determining the three-dimensional shape of objects in the environment, enabling the control of contact forces when manipulation by a telerobot or traversal by a vehicle is desired. Telerobotic manipulation in Earth orbit requires a system that can recognize known objects in spite of harsh lighting conditions and highly specular or absorptive surfaces. Planetary surface traversal requires a system that can recognize the surface shape and properties of an unknown and arbitrary terrain. Research on these two rather disparate types of vision systems is described. Author

N89-19881*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
A MULTI-SENSOR SYSTEM FOR ROBOTICS PROXIMITY OPERATIONS
J. B. CHEATHAM, C. K. WU, P. L. WEILAND (Rice Univ., Houston, TX.), and T. F. CLEGHORN *In its* 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 467-470 Nov. 1988
(Contract NCC9-16; NAG9-208)
Avail: NTIS HC A22/MF A01 CSCL 05/8

Robots without sensors can perform only simple repetitive tasks and cannot cope with unplanned events. A multi-sensor system is needed for a robot to locate a target, move into its neighborhood and perform operations in contact with the object. Systems that can be used for such tasks are described. Author

N89-19882*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
A METHODOLOGY FOR AUTOMATION AND ROBOTICS EVALUATION APPLIED TO THE SPACE STATION TELEROBOTIC SERVICER
JEFFREY H. SMITH, MAX GYANFI, KENT VOLKMER, and WAYNE ZIMMERMAN *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 471-479 Nov. 1988
(Contract NAS7-918)
Avail: NTIS HC A22/MF A01 CSCL 05/8

The efforts of a recent study aimed at identifying key issues and trade-offs associated with using a Flight Telerobotic Servicer (FTS) to aid in Space Station assembly-phase tasks is described. The use of automation and robotic (A and R) technologies for large space systems would involve a substitution of automation capabilities for human extravehicular or intravehicular activities (EVA, IVA). A methodology is presented that incorporates assessment of candidate assembly-phase tasks, telerobotic performance capabilities, development costs, and effect of operational constraints (space transportation system (STS), attached payload, and proximity operations). Changes in the region of cost-effectiveness are examined under a variety of systems design assumptions. A discussion of issues is presented with focus on three roles the FTS might serve: (1) as a research-oriented testbed to learn more about space usage of telerobotics; (2) as a research based testbed having an experimental demonstration orientation with limited assembly and servicing applications; or (3) as an operational system to augment EVA and to aid the construction of the Space Station and to reduce the programmatic (schedule) risk by increasing the flexibility of mission operations. Author

N89-19885*# Rockwell International Corp., Downey, CA.
DESIGN GUIDELINES FOR REMOTELY MAINTAINABLE EQUIPMENT
MARGARET M. CLARKE and DAVOUD MANOUCHEHRI *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 495-497 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 05/8

The quantity and complexity of on-orbit assets will increase significantly over the next decade. Maintaining and servicing these costly assets represent a difficult challenge. Three general methods are proposed to maintain equipment while it is still in orbit: an extravehicular activity (EVA) crew can perform the task in an unpressurized maintenance area outside any space vehicle; an intravehicular activity (IVA) crew can perform the maintenance in a shirt sleeve environment, perhaps at a special maintenance work station in a space vehicle; or a telerobotic manipulator can perform the maintenance in an unpressurized maintenance area at a distance from the crew (who may be EVA, IVA, or on the ground). However, crew EVA may not always be possible; the crew may have other demands on their time that take precedence. In addition, the orbit of the tasks themselves may be impossible for crew entry. Also crew IVA may not always be possible as option for equipment maintenance. For example, the equipment may be too large to fit through the vehicle airlock. Therefore, in some circumstances, the third option, telerobotic manipulation, may be the only feasible option. Telerobotic manipulation has, therefore, an important role for on-orbit maintenance. It is not only used for the reasons outlined above, but also used in some cases as backup to the EVA crew in an orbit that they can reach. Author

N89-20072*# Michigan Technological Univ., Houghton. Dept. of Mechanical Engineering.
MODEL EVALUATION, RECOMMENDATION AND PRIORITIZING OF FUTURE WORK FOR THE MANIPULATOR EMULATOR TESTBED Final Report

FREDERICK A. KELLY *In* NASA, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988, Volume 1 10 p Feb. 1989
Avail: NTIS HC A09/MF A01 CSCL 13/9

The Manipulator Emulator Testbed (MET) is to provide a facility capable of hosting the simulation of various manipulator configurations to support concept studies, evaluation, and other engineering development activities. Specifically, the testbed is intended to support development of the Space Station Remote Manipulator System (SSRMS) and related systems. The objective of this study is to evaluate the math models developed for the MET simulation of a manipulator's rigid body dynamics and the servo systems for each of the driven manipulator joints. Specifically, the math models are examined with regard to their amenability to pipeline and parallel processing. Based on this evaluation and the project objectives, a set of prioritized recommendations are offered for future work. Author

N89-20075*# Texas A&I Univ., Kingsville. Dept. of Civil and Mechanical Engineering.
INTELLIGENT CONTROL OF ROBOTIC ARM/HAND SYSTEMS FOR THE NASA EVA RETRIEVER USING NEURAL NETWORKS Final Report
ROBERT A. MCLAUCHLAN *In* NASA, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988, Volume 2 15 p Feb. 1989
Avail: NTIS HC A09/MF A01 CSCL 09/2

Adaptive/general learning algorithms using varying neural network models are considered for the intelligent control of robotic arm plus dextrous hand/manipulator systems. Results are summarized and discussed for the use of the Barto/Sutton/Anderson neuronlike, unsupervised learning controller as applied to the stabilization of an inverted pendulum on a cart system. Recommendations are made for the application of the controller and a kinematic analysis for trajectory planning to simple object retrieval (chase/approach and capture/grasp) scenarios in two dimensions. Author

N89-20082*# East Texas State Univ., Commerce. Dept. of Computer Science.
VISUAL PERCEPTION AND GRASPING FOR THE EXTRAVEHICULAR ACTIVITY ROBOT Final Report
SCOTT A. STARKS *In* NASA, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988, Volume 2 14 p Feb. 1989
Avail: NTIS HC A09/MF A01 CSCL 13/9

The development of an approach to the visual perception of object surface information using laser range data in support of robotic grasping is discussed. This is a very important problem area in that a robot such as the EVAR must be able to formulate a grasping strategy on the basis of its knowledge of the surface structure of the object. A description of the problem domain is given as well as a formulation of an algorithm which derives an object surface description adequate to support robotic grasping. The algorithm is based upon concepts of differential geometry namely, Gaussian and mean curvature. Author

11

MATERIALS

Includes mechanical properties of materials, and descriptions and analyses of different structural materials, films, coatings, bonding materials and descriptions of the effects of natural and induced space environments.

A89-10535
MATERIALS AND CONSTRUCTION TECHNIQUES FOR LARGE ORBITAL STRUCTURES [WERKSTOFFE UND BAUWEISEN FUER GROSSE ORBITALSTRUKTUREN]
H. W. BERGMANN (DFVLR, Brunswick, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 414-420. In German. refs
(DGLR PAPER 87-128)

European plans for the development of an orbital infrastructure are reviewed, with a focus on design concepts and their materials requirements. The history of space-station planning is recalled; the currently available materials and designs are surveyed, and particular attention is given to modular truss structures which can be easily unfolded and/or assembled in space, advanced CFRPs for light weight and high stability, and the need for long service life (20-30 years). Extensive diagrams, drawings, graphs, photographs, and tables of numerical data are provided. T.K.

A89-11893
MECHANISM OF RADIATION-INDUCED DEGRADATION IN MECHANICAL PROPERTIES OF POLYMER MATRIX COMPOSITES
SHIGENORI EGUSA (Takasaki Radiation Chemistry Research Establishment, Japan) Journal of Materials Science (ISSN 0022-2461), vol. 23, Aug. 1988, p. 2753-2760. refs

Four kinds of polymer matrix composites and two kinds of pure resins (epoxy and polyimide) were irradiated at room temperature by gamma rays from a Co-60 source or by 2-MeV electrons from an accelerator. Mechanical tests were then carried out at 77 K and room temperature. It is found that the mechanical properties of the composites depend on the irradiation dose and that this dependence varies not only with the combination of the filler (E-glass or carbon fiber cloth) and the matrix resin but also on the test temperature. Based on a comparison between the dose dependence of the composites and that of the pure resins, a mechanism of radiation-induced degradation of polymer matrix composites is proposed. V.L.

A89-17634#
MATERIALS SCIENCES RESEARCH IN SPACE BY TELESCIENCE
E. BENNETT, H. P. SCHMIDT, and B. FEUERBACHER (DFVLR, Rechenzentrum Koeln-Porz, Cologne, Federal Republic of Germany) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p. refs
(IAF PAPER 88-016)

Advanced telescience concepts are introduced and discussed. The various aspects of telescience are analyzed in terms of their relative importance for experimentation in a Space Station environment with particular emphasis on microgravity research. User requirements and their technological implications are outlined. An experiment planned for a facility on the German D-2 Spacelab mission is analyzed as a prototype for the implementation of some advanced telescience techniques, including interactive control. Emphasis is placed on advanced human/machine interfaces on ground. Such interfaces support full text and graphics capabilities and provide a transparent, fast, simple and integrated environment for experiment observation and control. Finally, the requirements and their ramifications for implementing a true telescience environment are analyzed. Author

A89-23415
ABLATION OF MATERIALS IN THE LOW-EARTH ORBITAL ENVIRONMENT
R. R. LAHER and L. R. MEGILL (Utah State University, Logan) Planetary and Space Science (ISSN 0032-0633), vol. 36, Dec. 1988, p. 1497-1507. Research supported by Morton Thiokol, Inc. refs

The ablation by atmospheric gas particles of materials exposed on the external ram surfaces of a spacecraft in LEO is examined. A physical sputtering model is used to estimate the physical sputtering rates of materials in LEO as a function of orbital altitude in the 100-1000 km range. It is found that the effects of physical sputtering range from significant mass loss after only a few months of exposure time for some materials to no observable effects after tens of years for other materials. Chemical sputtering rates by atomic oxygen and calculated physical sputtering rates are compared. The implications of this work for the Tethered Satellite System, the Space Station, and long-duration exposure facilities are discussed. R.B.

A89-25489#
INVESTIGATION OF ESD HAZARD FOR LARGE SPACE SOLAR ARRAYS CONFIGURED WITH GFRP/KAPTON SUBSTRATE
JOHN S. ARCHER, HANS S. RAUSCHENBACH, and N. JOHN STEVENS (TRW, Inc., Redondo Beach, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs (AIAA PAPER 89-0617)

The in-orbit failures of thin Kapton dielectric sheets in solar arrays were reviewed. From the data reported in the literature, supplemented by tests simulating high voltage breakdowns on substrate materials, design recommendations for future lightweight solar arrays were drawn. System configurations are identified which will minimize the hazard and improve the robustness of solar arrays with respect to electrostatic-discharge-induced substrate shorts. It is suggested that, for a 10-year-life spacecraft in geosynchronous orbit, the maximum dc voltage stress for 0.001-in-thick Kapton dielectrics be kept below 25 V. For 0.002-in-thick Kapton dielectrics, a maximum dc stress level of 40 V is estimated, and for 0.003 in, 50 V. Author

A89-28642* Brown Univ., Providence, RI.
BOUNDARY IDENTIFICATION FOR 2-D PARABOLIC PROBLEMS ARISING IN THERMAL TESTING OF MATERIALS
H. T. BANKS (Brown University, Providence, RI) and FUMIO KOJIMA (NASA, Langley Research Center, Hampton, VA) IN: IEEE Conference on Decision and Control, 27th, Austin, TX, Dec. 7-9, 1988, Proceedings. Volume 2. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1678-1683. refs (Contract NSF MCS-85-04316; F49620-86-C-0111; NAS1-18107)

Problems on the identification of two-dimensional spatial domains arising in the detection and characterization of structural flaws in materials are considered. For a thermal diffusion system with external boundary input, observations of the temperature on the surface are used in an output least square approach. Parameter estimation techniques based on the method of mappings are discussed, and approximation schemes are developed based on a finite-element Galerkin approach. Theoretical convergence results for computational techniques are given, and the results are applied to the identification of two kinds of boundary shapes. I.E.

A89-29298* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ESCA STUDY OF KAPTON EXPOSED TO ATOMIC OXYGEN IN LOW EARTH ORBIT OR DOWNSTREAM FROM A RADIO-FREQUENCY OXYGEN PLASMA
MORTON A. GOLUB, THEODORE WYDEVEN (NASA, Ames Research Center, Moffett Field, CA), and ROBERT D. CORMIA (Surface Science Laboratories, Mountain View, CA) Polymer Communications (ISSN 0263-6476), vol. 29, Oct. 1988, p. 285-288. refs

The ESCA spectra of Kapton polyimide film exposed to atomic oxygen O(3P), either in low earth orbit (LEO) on the STS-8 Space Shuttle or downstream from a radio-frequency oxygen plasma, were compared. The major difference in surface chemistry induced by the two types of exposure to O(3P), both of which caused surface recession (etching), was a much larger uptake of oxygen by Kapton etched in the O2 plasma than in LEO. This difference is attributed to the presence of molecular oxygen in the plasma reactor and its absence in LEO: in the former case, O2 can react with radicals generated in the Kapton molecule as it etches, become incorporated in the etched polymer, and thereby yield a higher steady-state 'surface oxidation' level than in LEO. Author

A89-30045
FLUENCE EQUIVALENCY OF MONOENERGETIC AND NONMONOENERGETIC IRRADIATION OF THERMAL CONTROL COATINGS [EKVIVALENTNOST' FLIUENSOV MONO- I NEMONOENERGETICHESKOGO VOZDEISTVIIA NA TERMOREGULIRUIUSHCHIE POKRYTIIA]
G. G. SOLOV'EV and A. P. GRASHCHENKO Fizika i Khimiia Obrabotki Materialov (ISSN 0015-3214), Jan.-Feb., p. 54-56. In Russian.

When using monoenergetic irradiation to simulate the effect of irradiation with a wide energy distribution acting on the external surfaces of spacecraft, the fluence of monoenergetic radiation equivalent to that of natural radiation must be calculated. Here, expressions for calculating the equivalent fluences are presented for three types of models of the radiation-optical degradation of thermal control coatings. V.L.

A89-30404
ELECTRON RADIATION EFFECTS ON MODE II INTERLAMINAR FRACTURE TOUGHNESS OF GFRP AND CFRP COMPOSITES
N. TAKEDA (Tokyo, University, Japan), M. TOHDOH, and K. TAKAHASHI (Kyushu University, Kasuga, Japan) SAMPE Quarterly (ISSN 0036-0821), vol. 20, Jan. 1989, p. 27-32. refs

The degradation properties of epoxy based fiber-reinforced plastics (FRP) composites irradiated by high-energy electrons were studied using the mode II interlaminar fracture toughness G(11c), measured by end-notched flexure tests. The radiation-induced degradation mechanisms were investigated through G(11c) and the scanning electron micrographs of fracture surfaces. For graphite FRP, the significant decrease in G(11c) was found. Debonding of glass fibers and epoxy matrix (or degradation of silane coupling agents) plays an important role in degradation in addition to resin degradation. Thus, the improvement of the radiation resistance of fiber-resin interfaces as well as matrix itself is of supreme importance in order to increase the radiation resistance of graphite FRP. For carbon FRP, on the other hand, no degradation in fiber-resin interfaces was found and the slight decrease in G(11c) seems to be due to the resin degradation. Author

A89-30715#
THERMAL DISTORTION BEHAVIOUR OF GRAPHITE REINFORCED ALUMINUM SPACE STRUCTURES
D. G. ZIMCIK (CDC, Communications Research Centre, Ottawa, Canada) and B. M. KOIKE (Composite Tecnologia, Sao Paulo, Brazil) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 632-639. refs (AIAA PAPER 89-1228)

The thermal distortion of graphite reinforced aluminum is evaluated, and its performances is compared with that of graphite/epoxy. The analysis introduces the concept of the total thermal distortion coefficient (TTDC) which enables the optimization of laminate ply configuration for minimum thermal distortion. For graphite/aluminum laminates, minimum TTDC values are found to be constant with stacking angle, making it possible to satisfy stiffness or strength requirements with no thermal distortion penalty. A design approach using the TTDC coefficient to optimize material mechanical properties with minimum thermal distortion is presented and illustrated for the case of a large (15 x 1.5 m) slotted waveguide planar array SAR antenna. V.L.

N89-11776*# National Aeronautics and Space Administration, Washington, DC.
MATERIALS AND STRUCTURES
SAMUEL L. VENNERI *In its* Technology for Future NASA Missions: Civil Space Technology Initiative (CSTI) and Pathfinder p 315-355 Sep. 1988
Avail: NTIS HC A23/MF A01 CSCL 22/1

Information on materials and structures for use in space is given in viewgraph form. Information is given on the Materials and Structures Division of NASA's Office of Aeronautics and Space Technology. The Division's space research and development budget is given. Further information is given on space materials and structures, space environmental effects, radiation effects, high temperature materials research, metal matrix composites, SiC fiber reinforced titanium alloys, structural dynamics, and control of flexible structures. R.J.F.

N89-11823# European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk (Netherlands). Structures and Mechanisms Div.
COMPOSITES DESIGN HANDBOOK FOR SPACE STRUCTURE APPLICATIONS, VOLUME 1
D. C. G. EATON Dec. 1986 462 p
(ESA-PSS-03-1101-ISSUE-1-VOL-1; ISSN-0379-4059; ETN-88-93161) Avail: NTIS HC A20/MF A01

Composite material properties and applications; calculation methods for laminates; and composites design aspects for ESA programs are presented. ESA

N89-12590*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
MATERIALS SELECTION FOR LONG LIFE IN LEO: A CRITICAL EVALUATION OF ATOMIC OXYGEN TESTING WITH THERMAL ATOM SYSTEMS
S. L. KOONTZ, J. KUMINECZ, L. LEGER, and P. NORDINE *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 66-88 1988
Avail: NTIS HC A21/MF A01 CSCL 07/4

The use of thermal atom test methods as a materials selection and screening technique for low-Earth orbit (LEO) spacecraft is critically evaluated. The chemistry and physics of thermal atom environments are compared with the LEO environment. The relative reactivities of a number of materials determined to be in thermal atom environments are compared to those observed in LEO and in high quality LEO simulations. Reaction efficiencies measured in a new type of thermal atom apparatus are one-hundredth to one-thousandth those observed in LEO, and many materials showing nearly identical reactivities in LEO show relative reactivities differing by as much as a factor of 8 in thermal atom systems. A simple phenomenological kinetic model for the reaction of oxygen atoms with organic materials can be used to explain the differences in reactivity in different environments. Certain specific thermal test environments can be used as reliable materials screening tools. Using thermal atom methods to predict material lifetime in LEO requires direct calibration of the method against LEO data or high quality simulation data for each material. Author

N89-13504# Joint Publications Research Service, Arlington, VA.
CONTINUOUS FORMING OF CARBON/THERMOPLASTICS COMPOSITE BEAMS
YOSHIAKI SAKATANI, YASUHIRO YAMAGUCHI, and MIKINE YOSHIDA *In its* JPRS Report: Science and Technology. Japan: 12th Composite Materials Symposium p 22-25 23 Sep. 1988 Transl. into ENGLISH from Daijunikai Fukugo Zairyo Symposium (Koen Yoshishu), (Tokyo, Japan), 22-23 Oct. 1987 p 91-92
Avail: NTIS HC A05/MF A01

The continuous forming method of thin, long structural elements with a view to applications for future large-sized space structures is now being developed. Using a band plate shaped material of high elasticity type carbon fiber/PEEK, studies have been conducted on the basic processing conditions for passing it between rolls in stages and continuously forming it into a hat shape. Optimum forming conditions such as the optimum forming temperature and optimum speed have been ascertained by gaining an understanding of formability data on materials from the forming tests conducted by the basic testing machines and from quality evaluation of the formed materials. Author

N89-14914*# College of William and Mary, Williamsburg, VA. Dept. of Chemistry.
RADIATION EFFECTS ON POLYMERIC MATERIALS Abstract Only
RICHARD L. KIEFER *In* Hampton Inst., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988 p 72-74 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 11/3

It is important to study changes in properties of polymeres after irradiation with charged particles, with ultraviolet radiation, and with combinations of both. An apparatus for this purpose has been built at the NASA Langley Research Center. It consists of a chamber 9 inches in diameter and 9 inches high with a port for an electron gun, another port for a mass spectrometer, and a quartz window through which an ultraviolet lamp can be focused. The chamber, including the electron gun and the mass spectrometer, can be evacuated to a pressure of 10 to the 8th power torr. A sample placed in the chamber can be irradiated with electrons and ultraviolet radiation separately, sequentially, or simultaneously, while volatile products can be monitored during all irradiations with the mass spectrometer. The apparatus described above has been used to study three different polymer films: lexan; a polycarbonate; P1700, a polysulfone; and mylar, a polyethylene terephthalate. All three polymers had been studied extensively with both electrons and ultraviolet radiation separately, but not simultaneously. Also, volatile products had not been monitored during irradiation for the materials. A high electron dose rate of 530 Mrads/hr was used so that a sufficient concentration of volatile products would be formed to yield a reasonable mass spectrum. Author

N89-15014*# Texas A&M Univ., College Station. Dept. of Geology.
VOLATILIZATION-DEVOLATILIZATION REACTIONS
M. C. GILBERT, D. M. ANDERSON, A. HAJASH, E. HOSKINS, and R. K. POPP *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 4 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 07/4

Experiments that explore chemical and physical aspects of volatilization reactions that require the microgravity and low pressure in or near the projected Space Station are proposed. Author

N89-15232*# Virginia Univ., Charlottesville. Dept. of Materials Science.
ENVIRONMENT ASSISTED DEGRADATION MECHANISMS IN ADVANCED LIGHT METALS Progress Report, 1 Jun. - 31 Dec. 1988
R. P. GANGLOFF, G. E. STONER, and R. E. SWANSON Jan. 1989 169 p
(Contract NAG1-7452)
(NASA-CR-181049; NAS 1.26:181049; UVA/528266/MS89/103)
Avail: NTIS HC A08/MF A01 CSCL 11/6

A multifaceted research program on the performance of advanced light metallic alloys in aggressive aerospace environments, and associated environmental failure mechanisms was initiated. The general goal is to characterize alloy behavior quantitatively and to develop predictive mechanisms for environmental failure modes. Successes in this regard will provide the basis for metallurgical optimization of alloy performance, for chemical control of aggressive environments, and for engineering life prediction with damage tolerance and long term reliability. B.G.

N89-16986*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
REFRACTORY METAL ALLOYS AND COMPOSITES FOR SPACE NUCLEAR POWER SYSTEMS Final Report
ROBERT H. TITRAN, JOSEPH R. STEPHENS, and DONALD W. PETRASEK Sep. 1988 24 p Presented at the Metallurgical Society Fall Meeting, Chicago, IL, 27-29 Sep. 1988; sponsored in part by the Metallurgical Society of AIME and the American Society for Metals
(Contract DE-AI03-86SF-16310)
(NASA-TM-101364; E-4398; DOE/NASA/16310-8; NAS 1.15:101364) Avail: NTIS HC A03/MF A01 CSCL 11/6

Space power requirements for future NASA and other U.S. missions will range from a few kilowatts to megawatts of electricity. Maximum efficiency is a key goal of any power system in order to minimize weight and size so that the Space Shuttle may be used a minimum number of times to put the power supply into orbit. Nuclear power has been identified as the primary power source to meet these high levels of electrical demand. One method to achieve maximum efficiency is to operate the power supply, energy conservation system, and related components at relatively high temperatures. For systems now in the planning stages, design temperatures range from 1300 K for the immediate future to as high as 1700 K for the advanced systems. NASA Lewis Research Center has undertaken a research program on advanced technology of refractory metal alloys and composites that will provide baseline information for space power systems in the 1900's and the 21st century. Special emphasis is focused on the refractory metal alloys of niobium and on the refractory metal composites which utilize tungsten alloy wires for reinforcement. Basic research on the creep and creep-rupture properties of wires, matrices, and composites are discussed. Author

N89-18608*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
CHEMSEAL 3808-A2 PENETRATION INTO SMALL LEAK PATH
M. R. CARRUTH, JR. and R. F. DEHAYE Dec. 1988 22 p
(NASA-TM-100345; NAS 1.15:100345) Avail: NTIS HC A03/MF A01 CSCL 20/4

A possible fix to a leak in the oxidizer system of the Space Shuttle Discovery's attitude control system was proposed by MSFC. This fix involved the passing of a shuttlecock past the leaking Dynaflow fitting and sealing the vent tube containing the fitting with Chemseal 3808-A2. The question of whether the Chemseal 3808-A2 can flow into the leak path and provide a better seal was addressed analytically and by experiment to verify the analytical formula used. The results show that the equations are applicable and that the Chemseal will flow into the expected leak path and seal. Author

N89-19375 Salford Univ. (England).
HEAT TRANSFER PROPERTIES OF SATELLITE COMPONENT MATERIALS Ph.D. Thesis
STUART DONALD MCIVOR 1988 150 p
Avail: Univ. Microfilms Order No. BRD-83072

The thermal conductivities of samples of unidirectional fibre reinforced composites were measured both perpendicular to and parallel to the fibres. Two types of samples were measured, Fibredux 914 resin reinforced with R-Glass fibres, and Code 69 resin reinforced with GY80 carbon fibres. A model has been produced which can be used to predict the thermal conductivity of any rectangular unidirectional fibre reinforced composite lamina. The model was constructed using a method of finite difference analysis performed by a computer program written in FORTRAN. Three samples of Code 69 resin reinforced with GY70 carbon fibres were produced with their fibres aligned at 30, 45, and 60 deg to the horizontal and their thermal conductivities measured. In order to examine the accuracy of the model the values of the conductivities of these samples were compared with those calculated using the model. The heat transfer properties of thermal blankets used to insulate satellites were investigated. The heat flow across blankets, placed in a thermal vacuum chamber and subjected to similar temperature differentials as would be found in Earth orbit, was measured and the values for the effective thermal conductance and the effective emissivity of the blankets calculated. Dissert. Abstr.

N89-19385*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE EFFECTS OF SIMULATED SPACE ENVIRONMENTAL PARAMETERS ON SIX COMMERCIALLY AVAILABLE COMPOSITE MATERIALS
JOAN G. FUNK and GEORGE F. SYKES, JR. Apr. 1989 34 p
(NASA-TP-2906; L-16549; NAS 1.60:2906) Avail: NTIS HC A03/MF A01 CSCL 11/4

The effects of simulated space environmental parameters on microdamage induced by the environment in a series of commercially available graphite-fiber-reinforced composite materials were determined. Composites with both thermoset and thermoplastic resin systems were studied. Low-Earth-Orbit (LEO) exposures were simulated by thermal cycling; geosynchronous-orbit (GEO) exposures were simulated by electron irradiation plus thermal cycling. The thermal cycling temperature range was -250 F to either 200 F or 150 F. The upper limits of the thermal cycles were different to ensure that an individual composite material was not cycled above its glass transition temperature. Material response was characterized through assessment of the induced microcracking and its influence on mechanical property changes at both room temperature and -250 F. Microdamage was induced in both thermoset and thermoplastic advanced composite materials exposed to the simulated LEO environment. However, a 350 F cure single-phase toughened epoxy composite was not damaged during exposure to the LEO environment. The simuated GEO environment produced microdamage in all materials tested. Author

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INFORMATION AND DATA MANAGEMENT

Includes descriptions, requirements, and trade studies of different information and data system hardware and software, languages, architecture, processing and storage requirements for managing and monitoring of different systems and subsystems.

A89-10490
COMMUNICATION AND DATA PROCESSING [KOMMUNIKATION UND DATENVERARBEITUNG]
H. GREEN (AEG AG, Wedel, Federal Republic of Germany), J. CZECH (ANT Nachrichtentechnik GmbH, Backnang, Federal Republic of Germany), and H. REFFEL (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 38-45. In German.
(DGLR PAPER 87-094)

The design of a communication infrastructure for future European space activities is discussed, summarizing the recommendations of the FRG Planning Framework for High Technology and Space Flight (OHR). The current status of space and space-earth digital and voice communication is briefly surveyed; the roles of GEO relay satellites, ground local-area and wide-area digital networks, and internetwork gateways in an advanced infrastructure are described and illustrated with extensive diagrams; and the technological and design requirements for realizing such a system are indicated in tables. It is concluded that, although revolutionary breakthroughs are not necessary, a preparatory communication R&D program dedicated specifically to the OHR goals and cooperating with ongoing OHR programs in other fields should be initiated as soon as possible. T.K.

A89-11714* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
EXPERT SYSTEM ISSSUES IN AUTOMATED, AUTONOMOUS SPACE VEHICLE RENDEZVOUS
MARY ANN GOODWIN (NASA, Johnson Space Center, Houston, TX) and DANIEL C. BOCHSLER (LinCom Corp., Houston, TX) IN: Applications of artificial intelligence V; Proceedings of the Meeting, Orlando, FL, May 18-20, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 71-78. refs

The problems involved in automated autonomous rendezvous are briefly reviewed, and the Rendezvous Expert (RENEX) expert system is discussed with reference to its goals, approach used, and knowledge structure and contents. RENEX has been developed to support streamlining operations for the Space Shuttle and Space Station program and to aid definition of mission requirements for the autonomous portions of rendezvous for the Mars Surface Sample Return and Comet Nucleus Sample return unmanned missions. The experience with REMEX to date and recommendations for further development are presented. V.L.

A89-11808
EXPERT SYSTEM TECHNOLOGY FOR THE SPACE STATION COMMUNICATIONS AND TRACKING SYSTEM
M. S. CRONE, P. M. JULICH, E. G. DASH, and W. D. WAVERING (Harris Corp., Melbourne, FL) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 31-38. refs

This paper describes research into the use of expert system technology for the management of the Communications and Tracking System for the Space Station. The CAMERA (control and monitoring equipment resource allocation) expert system was developed under a NASA contract with JSC to minimize crew workload in managing the communications of the Space Station. It provides for automatic management of communications resources, diagnosis of faults, and reconfiguration to restore communications automatically. The system utilizes a state-of-the-art man-machine interface to allow high level end-to-end service requests. The expert system interprets the requests, determines the equipment required to implement the service, and assigns the appropriate equipment to the service. The expert system then establishes the service automatically at the time requested and monitors the operation of the simulated system to diagnose faults and determine the appropriate procedures to restore the service. A graphical design tool allows the operator to define new services from existing service primitives. Graphical, hierarchical equipment schematics support both the simulation of faults as well as the diagnostic process. Symbolic models for the equipment and measurements are represented in an object-oriented manner.
Author

A89-11809
EXPERIMENTS WITH TEMPORAL REASONING APPLIED TO ANALYSIS OF TELEMETRY DATA
W. A. PERKINS and A. AUSTIN (Lockheed Artificial Intelligence Center, Palo Alto, CA) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 39-46. refs

A temporal reasoning capability was implemented in a generic expert system shell to increase the flexibility of knowledge representation for a variety of applications. Telemetry data were monitored via satellite (the Space Telescope), and use was made of the rotor controlled electronics bearing having such attributes as actual temperature of the bearing, wheel speed, and motor current. The use of time tags associated with attribute values makes it possible to diagnose different problems occurring at different times with the same component. K.K.

A89-15335* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
STARR - AN EXPERT SYSTEM FOR FAILURE DIAGNOSIS IN A SPACE BASED POWER SYSTEM
BRYAN WALLS (NASA, Marshall Space Flight Center, Huntsville, AL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 303-306.

Starr, a prototype expert system, is designed to monitor and model a space power system, recognize problem states, identify the failure, and recommend the proper action to be taken. The system was modeled on the autonomously managed power system (AMPS) breadboard at NASA-Marshall. An object-oriented approach was used for the Starr model. K.K.

A89-15336* Martin Marietta Corp., Denver, CO.
CONCURRENT DEVELOPMENT OF FAULT MANAGEMENT HARDWARE AND SOFTWARE IN THE SSM/PMAD
KENNETH A. FREEMAN, RICK WALSH (Martin Marietta Corp., Astronautics Group, Denver, CO), and DAVID J. WEEKS (NASA, Marshall Space Flight Center, Huntsville, AL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 307-312.

Space Station issues in fault management are discussed. The system background is described with attention given to design guidelines and power hardware. A contractually developed fault management system, FRAMES, is integrated with the energy management functions, the control switchgear, and the scheduling and operations management functions. The constraints that shaped the FRAMES system and its implementation are considered.
K.K.

A89-15337
FAULT TOLERANT INTELLIGENT CONTROLLER FOR SPACE STATION SUBSYSTEMS
H. BIGLARI (Boeing Aerospace Co., Huntsville, AL), C. CHENG, and G. VACHTSEVANOS (Georgia Institute of Technology, Atlanta) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 313-318. refs

An intelligent controller is described which uses a simplified fault detection and isolation algorithm in conjunction with an ICON-based environment to represent a subsystem, the control strategies associated with the subsystem, and the fault management techniques. Of particular interest in this paper is the potable water system of the Space Station's common module. The ICON-based application generator leads to increased design flexibility and reliability. K.K.

A89-15345* Tennessee Univ. Space Inst., Tullahoma.
DEVELOPMENT OF A COMPONENT CENTERED FAULT MONITORING AND DIAGNOSIS KNOWLEDGE BASED SYSTEM FOR SPACE POWER SYSTEM
S. C. LEE (Tennessee, University, Tullahoma) and LOUIS F. LOLLAR (NASA, Marshall Space Flight Center, Huntsville, AL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 377-382. refs

The overall approach currently being taken in the development of AMPERES (Autonomously Managed Power System Extendable Real-time Expert System), a knowledge-based expert system for fault monitoring and diagnosis of space power systems, is discussed. The system architecture, knowledge representation, and fault monitoring and diagnosis strategy are examined. A 'component-centered' approach developed in this project is described. Critical issues requiring further study are identified.
C.D.

A89-15347* Texas A&M Univ., College Station.
EXPERT SYSTEM STRUCTURES FOR FAULT DETECTION IN SPACEBORNE POWER SYSTEMS
KARAN WATSON, B. DON RUSSELL (Texas A & M University,

College Station), and IRENE HACKLER (NASA, Johnson Space Center, Houston, TX) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 389-394.

This paper presents an architecture for an expert system structure suitable for use with power system fault detection algorithms. The system described is not for the purpose of reacting to faults which have occurred, but rather for the purpose of performing on-line diagnostics and parameter evaluation to determine potential or incipient fault conditions. The system is also designed to detect high impedance or arcing faults which cannot be detected by conventional protection devices. This system is part of an overall monitoring computer hierarchy which would provide a full evaluation of the status of the power system and react to both incipient and catastrophic faults. An approximate hardware structure is suggested and software requirements are discussed. Modifications to CLIPS software, to capitalize on features offered by expert systems, are presented. It is suggested that such a system would have significant advantages over existing protection philosophy. Author

A89-15349
A DIAGNOSTIC EXPERT SYSTEM FOR SPACE-BASED ELECTRICAL POWER NETWORKS
EDWARD W. GHOLDSTON, DON F. JANIK, and GARTH LANE (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 401-406. refs

This paper focuses on the development of a prototype expert system which could be utilized to analyze the Space Station electrical power system. The diagnostic requirements of such a system are summarized, and the hierarchy of the expert system development is reviewed. The system hardware and software are described, and the program structure and rule base are examined. C.D.

A89-15350* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
COOPERATING EXPERT SYSTEMS FOR SPACE STATION - POWER/THERMAL SUBSYSTEM TESTBEDS
CARLA M. WONG (NASA, Ames Research Center, Moffett Field, CA), DAVID J. WEEKS (NASA, Marshall Space Flight Center, Huntsville, AL), GALE R. SUNDBERG (NASA, Lewis Research Center, Cleveland, OH), KATHLEEN L. HEALEY, and JEFFREY S. DOMINICK (NASA, Johnson Space Center, Houston, TX) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 407-414. refs

The Systems Autonomy Demonstration Project (SADP) is a NASA-sponsored series of increasingly complex demonstrations to show the benefits of integrating knowledge-based systems with conventional process control in real-time, real-world problem domains that can facilitate the operations and availability of major Space Station distributed systems. This paper describes the system design, objectives, approaches, and status of each of the testbed knowledge-based systems. Simplified schematics of the systems are shown. C.D.

A89-15383
A KNOWLEDGE-BASED LOAD FORECASTING AND MANAGEMENT TECHNIQUE FOR SPACE STATION POWER SYSTEMS
SAIFUR RAHMAN and MOUNIR BOUZGUENDA (Virginia Polytechnic Institute and State University, Blacksburg) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 615-620.

An integrated load forecasting/load management system for space station power systems is proposed which can generate a 10-minute photovoltaic energy profile on a 24-hour basis. The simulation is based on such factors as the extraterrestrial solar radiation, station orbital parameters, initial launch data, and time of the year. The method takes into account load control options, the space station operational requirements, and the available energy souces. R.R.

A89-16513#
A METHODOLOGY FOR MODELING LIFE-CYCLE PROCESSES
CHRISTINE M. KELLY (Mitre Corp., Houston, TX) and RONALD G. ROSS (Ronald G. Ross Associates, Houston, TX) IEEE, International Conference on Data Engineering, 4th, Los Angeles, CA, Feb. 2-4, 1988, Paper. 16 p.
(Contract F19628-86-C-0001)

Entity modeling is a technique used to describe the data architecture of a system. Behavior modeling is an extension of entity modeling which adds behavior and integrity constraint concepts to the entity model. A Behavior Model represents the dynamics of the system and formulates rules for maintaining a valid data model. Concepts defining Automatic Actions, Integrity Constraints, and Triggers are presented. Graphical representation of these concepts are shown superimposed on the data model. An area for which behavior modeling has application is in the analysis of life-cycle processes. A case study outlining a management plan for Space Station crew procedures is used to illustrate the life-cycle modeling technique. Author

A89-17630*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
TELESCIENCE, AN OPERATIONAL APPROACH TO SCIENCE INVESTIGATION
JAMES R. WEISS (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 11 p.
(IAF PAPER 88-011)

The NASA Science and Applications Information System, which is based on telescience and must provide remote interaction between information system services in space and on the ground, is discussed. An infrastructure of networked facilities and institutionally provided support services is being developed. The technologies involved with providing telescience capability are examined, including automated data management services, new data acquisition systems, user support environment for system access, and the capability to access heterogeneous data bases and computational facilities from remote locations. R.B.

A89-17631#
THE CONCEPT OF TELESCIENCE
J. DOUTRELEAU, J. C. DEGAVRE, J. F. LAFAY (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands), and N. WOOTTON (Logica Space and Defence Systems, Ltd., Cobham, England) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 8 p.
(IAF PAPER 88-012)

Telescience is a user concept. It describes a mode of payload operations whereby users can interactively control their payload in space on-board the Columbus elements, receiving data and sending control signals through an operational infrastructure including the On-Board Data Management System (DMS), the space segment (including Data Relay Satellites), the Operation Coordination centers. In order to achieve a high degree of operation friendliness, the design of the infrastructure needs to take into account the requirements of telescience operations. A Telescience Preparatory Program has been undertaken by the European Space Agency with the objective of defining the operational limits of the concept. Scientists, system designers and operators will participate in this evaluation. A so-called 'Telescience Test Bed', installed at ESTEC, will provide the tools for the verification of the system design specifications and the operations procedures. It will also constitute an experimental facility for the familiarization of potential

users with the interactive operation of payloads on Columbus. Author

A89-17675#
COLUMBUS STANDARD USER INTERFACES AND RESOURCES FOR APM/MTFF
A. MCGRATH, G. BOLTON, and K. KNOTT (ESA, Noordwijk, Netherlands) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 5 p.
(IAF PAPER 88-098)

This paper describes how the user relevant system requirements for the two manned elements of the Columbus Programme, the Attached Pressurized Module (APM) and the Man Tended Free Flyer (MTFF) have been derived. Starting points for the derivation were an initial design of the elements and a set of user specified Reference Payloads. The system requirements were finally established by iterating given configurations against these Reference Payloads. A second iteration was necessary to achieve a reasonable balance between individual resources such as volume, power, crew time, up/down loads. The Reference Payload scenario has been further developed to achieve functional and physical interface definition. Author

A89-18118#
THE NASA INFORMATION SYSTEM LIFE-CYCLE TRANSITION MANAGEMENT WITHIN THE SOFTWARE PROJECT
MICHAEL W. EVANS, W. M. WILSON, and D. SOVA IN: AIAA/IEEE Digital Avionics Systems Conference, 8th, San Jose, CA, Oct. 17-20, 1988, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 471-477. refs
(AIAA PAPER 88-3947)

The complexity and critical nature of mission software within NASA has necessitated the development of a structured process for acquiring and assuring software. This paper discusses NASA Information System Life-Cycle and Standard, the framework that NASA will use for developing major software-intensive projects like the Space Station. The objectives, relationships, and hierarchy of the process life cycles are examined, and the process design phases are discussed. The documentation scheme that has evolved from putting software in the information life-cycle context and the restructuring of the internal software documentation standards to reflect the documentation philosophy and accommodate mission risk are addressed. C.D.

A89-18139*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
REDUCING THE RISKS OF USING ADA ONBOARD THE SPACE STATION
TERRY D. HUMPHREY (NASA, Johnson Space Center, Houston, TX) IN: AIAA/IEEE Digital Avionics Systems Conference, 8th, San Jose, CA, Oct. 17-20, 1988, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 599-602. refs
(AIAA PAPER 88-3977)

In 1986, the Ada programming language was chosen by NASA as the primary computer programming language for the development of new software for the Space Station. Ada was selected based on the results of investigations coordinated through Johnson Space Center (JSC). These investigations resulted in the identification of a set of problems and risks associated with using software developed in Ada onboard the Space Station. But the risks associated with these problems were found to be of insufficient severity to outweigh the significant benefits and suitability of Ada for the project. However, since the selection of Ada for the Space Station Project, detailed investigations have continued at Johnson Space Center into the most important problems identified in using Ada. This paper discusses some of the specific solutions to problems which have been identified through these investigations and which are reducing the risks of using Ada onboard the Space Station. Author

A89-18167*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
THE SPACE STATION DATA MANAGEMENT SYSTEM - AVIONICS THAT INTEGRATE
VIRGINIA WHITELAW (NASA, Johnson Space Center, Houston, TX) IN: AIAA/IEEE Digital Avionics Systems Conference, 8th, San Jose, CA, Oct. 17-20, 1988, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 767-774.
(AIAA PAPER 88-3972)

The Space Station Data Management System (DMS) comprises the networked computers, mass storage, workstations, and instrumentation interfaces required to support onboard systems and payload operations. This paper gives an overview of the current DMS architecture and discusses its role as onboard integrator in four of its major functional areas: (1) data communication; (2) data processing; (3) data administration, storage and retrieval; and (4) data presentation at the human-computer interface. Author

A89-18169*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
THE ROLE OF STANDARDS IN INTEGRATING THE SPACE BASED AND GROUND BASED DATA SYSTEMS OF THE SPACE STATION INFORMATION SYSTEM
WALTER S. MARKER, JR. (NASA, Johnson Space Center, Houston, TX) IN: AIAA/IEEE Digital Avionics Systems Conference, 8th, San Jose, CA, Oct. 17-20, 1988, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 780-787.
(AIAA PAPER 88-3974)

This paper develops four criteria that are often associated with problems developing at interfaces between the subsystems of the Space Station Information System (SSIS). These criteria are then applied to data communication interfaces that exist throughout the principal components that comprise SSIS. The criteria were utilized to forecast the likeliness of problems developing at particular interfaces and to identify potential solutions to mitigate the risk. Author

A89-18171#
SPACE STATION DATA MANAGEMENT SYSTEM ARCHITECTURE
WILLIAM A. MADDEN (IBM, Systems Integration Div., Houston, TX) and PATRICK P. WILHELM (McDonnell Douglas Astronautics Co., Huntington Beach, CA) IN: AIAA/IEEE Digital Avionics Systems Conference, 8th, San Jose, CA, Oct. 17-20, 1988, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 792-798. refs
(AIAA PAPER 88-3979)

The Space Station Data Management System (DMS) is the first large-scale distributed processing network for long-term use in space. It provides a growth-oriented base for automation to increase crew productivity, thus enhancing the Space Station's operational capabilities. This paper gives an overview of a proposed architecture and preliminary design which satisfy the NASA/JSC requirements for the DMS. The overall proposed architecture is: (1) open and nonproprietary avoiding the cost implications of custom solutions, (2) structured and modular to support growth and technology insertion, and (3) based on standards for hardware and software interfaces to isolate system complexities from the users and simplify integration. Author

A89-18331#
CALS AND THE SPACE STATION - THE NEED FOR COMPUTER-AIDED ACQUISITION AND LOGISTICS SUPPORT
ALBERG D. HORTON (Honeywell, Inc., Largo, FL) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 7 p.
(AIAA PAPER 88-4756)

The Computer Aided Acquisition and Logistics System (CALS) developed under DOD sponsorship will generate, access, manage, distribute, and integrate data concerning the logistical requirements

of large vehicles and systems. Attention is presently given to CALS's application to NASA Space Station logistics considerations. The application of CALS standards is expected to simplify work methodology and lower development costs. CALS is noted to be applicable to several major systems and functions of the Space Station that are expected to be highly automated. O.C.

A89-19862#
INTEGRATED CNI TERMINAL SOFTWARE ARCHITECTURE
RICHARD A. BRYSON (TRW, Inc., Military Electronics and Avionics Div., San Diego, CA) AIAA, Digital Systems Conference, 8th, San Jose, CA, Oct. 17-20, 1988. 9 p.
(AIAA PAPER 88-4022)

This paper describes the current architecture and features of the integrated communication-navigation-identification (CNI) family of integrated avionic systems and how they apply to the PAVE PILLAR preferred system architecture for the next generation of avionics. The key features are a hierarchically distributed design from the avionics authority (pilot, mission tape/disk or mission data computer) down through the CNI subsystem and into the line-replaceable modules, infusion of expert system technology into the integrated built-in test and maintenance segment, and an integration of the resource management and integrated built-in test and maintenance segments at each level of the hierarchy to effect efficient dynamic reconfiguration of the common modules of these systems. Author

A89-20109* NASA Space Station Program Office, Reston, VA.
DATA INTERFACES TO THE SPACE STATION INFORMATION SYSTEM
RICHARD CARPER (NASA, Space Station Freedom Program Office, Reston, VA) and FRITZ SCHULZ (Ford Aerospace Corp., Space Missions Group, Reston, VA) IN: EASCON '88; Proceedings of the Twenty-first Annual Electronics and Aerospace Conference, Arlington, VA, Nov. 9-11, 1988. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 77-85. refs

The general form of the information system to be implemented to provide the broad and flexible services required to support the diverse needs of the U.S. Space Station is discussed. Emphasis is placed on the interfaces to the SSIS (Space Station Information System) and major interfaces within the SSIS. A central theme of the SSIS is the use of international standards, where appropriate and available. These standards include those of the International Organization for Standards (ISO), the Telegraph and Telephone Consultative Committee (CCITT), and the Consultative Committee for Space Data Systems (CCSDS). The specific standards selected or under consideration are enumerated. The effect of the selections on the interfaces visible to users of the SSIS are described, and a status report on the progress of official adoption of the standards is presented. I.E.

A89-21808
INTEGRATED RESOURCE SCHEDULING IN A DISTRIBUTED SCHEDULING ENVIRONMENT
DAVID ZOCH and GARDINER HALL (Ford Aerospace Corp., Seabrook, MD) (NASA, 1988 Goddard Conference on Space Applications of Artificial Intelligence, Greenbelt, MD, May 24, 1988) Telematics and Informatics (ISSN 0736-5853), vol. 5, no. 3, 1988, p. 229-240. Previously announced in STAR as N88-30342. refs

The Space Station era presents a highly-complex multi-mission planning and scheduling environment exercised over a highly distributed system. In order to automate the scheduling process, customers require a mechanism for communicating their scheduling requirements to NASA. A request language that a remotely-located customer can use to specify his scheduling requirements to a NASA scheduler, thus automating the customer-scheduler interface, is described. This notation, Flexible Envelope-Request Notation (FERN), allows the user to completely specify his scheduling requirements such as resource usage, temporal constraints, and scheduling preferences and options. The FERN also contains mechanisms for representing schedule and resource availability information, which are used in the inter-scheduler inconsistency resolution process. Additionally, a scheduler is described that can accept these requests, process them, generate schedules, and return schedule and resource availability information to the requester. The Request-Oriented Scheduling Engine (ROSE) was designed to function either as an independent scheduler or as a scheduling element in a network of schedulers. When used in a network of schedulers, each ROSE communicates schedule and resource usage information to other schedulers via the FERN notation, enabling inconsistencies to be resolved between schedulers. Individual ROSE schedulers are created by viewing the problem as a constraint satisfaction problem with a heuristically guided search strategy. Author

A89-22623#
COES - AN APPROACH TO OPERATIONS AND CHECK-OUT STANDARDS
R. F. WORRON (ESA, Automation and Informatics Dept., Noordwijk, Netherlands) ESA Bulletin (ISSN 0376-4265), no. 56, Nov. 1988, p. 58-65.

The accumulated costs of testing and operating a spacecraft form one of the major cost elements of any space project. As the complexity of projects increases, so do the associated costs of testing and mission control. To limit these cost factors, more account must be taken of testability and operability during the design phases of new projects. Author

A89-23079
FAULT TOLERANT DATA NETWORK FOR USE IN SPACE
R. P. MATHUR (British Aerospace, PLC, Space and Communications Div., Stevenage, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 42, Jan. 1989, p. 27-34.

Such large-scale manned space systems as spaceplanes and space stations call for the development of a data network capable of serving up to 100 users with high reliability, in virtue of tolerance to multiple failures, as well as the ability to transport data at rates of up to 200 Mbits/sec and the incorporation of easy maintenance and servicing routines. Attention is given to the ESA-sponsored development of the reliable on-board data network, 'Rodnet', which is based on a broadcast-tree architecture and uses optical fibers as the transmission medium, in conjunction with a novel access protocol and failure-tolerance mechanism. The network allows the use of different-priority levels for data packets, with guaranteed maximum access time for high-priority packets. O.C.

A89-27912* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
TELESCIENCE CONCEPT FOR HABITAT MONITORING AND CONTROL
DARYL RASMUSSEN (NASA, Ames Research Center, Moffett Field, CA), VICKI JOHNSON, and ARSHAD MIAN SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 13 p. refs
(SAE PAPER 881121)

The operational environment for life sciences on the Space Station will incorporate telescience, a new set of operational modes for conducting science and operations remotely. This paper presents payload functional requirements for Space Station Life Sciences habitat monitoring and control and describes telescience concepts and technologies which meet these requirements. Special considerations for designing sensors and effectors to accommodate future evolutions in technology are discussed. Author

A89-28740
A DEBUGGER FOR ADA TASKING
ANNE F. BRINDLE (Boeing Aerospace, Seattle, WA), RICHARD N. TAYLOR (California, University, Irvine), and DAVID F. MARTIN (California, University, Los Angeles) IEEE Transactions on Software Engineering (ISSN 0098-5589), vol. 15, March 1989, p. 293-304. Research supported by the Aerospace Corp. refs
(Contract NSF DCR-84-51421; NSF DCR-85-02558)

The capabilities needed in an Ada debugger are discussed in light of the language's tasking constructs, and the design for a debugger is presented which operates in concert with a single-processor Ada interpreter. This debugger design dem-

onstrates the extensions to sequential debugging techniques that are necessary to handle concurrency, and shows that significant debugging functionality can be provided even without the inclusion of automatic error diagnosis methods. The issues considered here include isolation of effects and display of the full dynamic execution status, both of which are essential to diagnosis of concurrent programs. I.E.

A89-31009
APPLICATION FOR SPACECRAFT OF THE 90'S USING MICRODACS TECHNOLOGY
PAUL HORN (SCI Technology, Inc., Huntsville, AL) IN: ITC/USA/'88; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 17-20, 1988. Research Triangle Park, NC, Instrument Society of America, 1988, p. 105-109.

Recent developments in electronics have made possible the miniaturization of many of the subsystem components associated with a typical spacecraft data acquisition and control system. This paper describes a low power consumption, fault tolerant, high performance data acquisition and control system design utilizing third generation hardware. The system includes built-in test autonomy, redundancy management, and fault tolerant communication busses, and supports multiprocessing with up to five 35 million instructions per second (Mips) processors. Author

A89-31020
SPACEBORNE RECORDING SYSTEMS FOR THE SPACE STATION ERA
JERRY MUENCH (Odetics, Inc., Space Div., Anaheim, CA) IN: ITC/USA/'88; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 17-20, 1988. Research Triangle Park, NC, Instrument Society of America, 1988, p. 305-316.

A detailed review of spaceborne magnetic tape recorder technology from the late 1970s to the Space Station era is presented. Background information indicates that the oft maligned space tape recorder has continued to demonstrate improving reliability since the marginal performances throughout the 1960s. Specifically, the SPOT recorder is reviewed in technical detail to show its evolution through the LANDSAT 6 and 7 versions, JERS-1, and finally the proposed ultimate version for the Space Station/EOS. Enabling technologies include active tape tracking, magnetic recording head advances, and extensive use of application-specific integrated circuit devices to reduce the EEE piece part count. The suitability of the proposed Space Station/EOS recorder technologies for advanced future applications requiring data rates to 1 Gops and storage capacities to 1 x 10 to the 12th bits is discussed. Author

A89-31033*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
DESIGN OF SPACE STATION ERA MASS STORAGE SYSTEMS
WARD P. HORNER and JAMES R. CHESNEY (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: ITC/USA/'88; Proceedings of the International Telemetering Conference, Las Vegas, NV, Oct. 17-20, 1988. Research Triangle Park, NC, Instrument Society of America, 1988, p. 451-460.

The architecture, components, and technical approach for a Space Station era mass storage system prototype are described. The primary data storage needs call for such functions as line outage recording, rate buffering, data archiving, and level zero type processing. The prototype mass storage system hardware will be configurable to support three modes of operation at up to 300 Mbps. The system architecture consists of two distinct components: a configurable high-level mass storage control system and a basic storage kernal. K.K.

A89-31082*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
KNOWLEDGE ACQUISITION FOR AUTONOMOUS SYSTEMS
HENRY LUM (NASA, Ames Research Center, Moffett Field, CA) and EWALD HEER (Heer Associates, Inc., La Canada, CA) IN: Machine intelligence and autonomy for aerospace systems. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 113-124. refs

Knowledge-based capabilities for autonomous aerospace systems, such as the NASA Space Station, must encompass conflict-resolution functions comparable to those of human operators, with all elements of the system working toward system goals in a concurrent, asynchronous-but-coordinated fashion. Knowledge extracted from a design database will support robotic systems by furnishing geometric, structural, and causal descriptions required for repair, disassembly, and assembly. The factual knowledge for these databases will be obtained from a master database through a technical management information system, and it will in many cases have to be augmented by domain-specific heuristic knowledge acquired from domain experts. O.C.

N89-10077*# Stanford Telecommunications, Inc., McLean, VA.
A HIERARCHICALLY DISTRIBUTED ARCHITECTURE FOR FAULT ISOLATION EXPERT SYSTEMS ON THE SPACE STATION
STEVE MIKSELL and SUE COFFER *In* NASA, Goddard Space Flight Center, Proceedings of 1987 Goddard Conference on Space Applications of Artificial Intelligence (AI) and Robotics 9 p 1987 (Contract NAS5-29280)
Avail: NTIS HC A99/MF E03 CSCL 05A

The Space Station Axiomatic Fault Isolating Expert Systems (SAFTIES) system deals with the hierarchical distribution of control and knowledge among independent expert systems doing fault isolation and scheduling of Space Station subsystems. On its lower level, fault isolation is performed on individual subsystems. These fault isolation expert systems contain knowledge about the performance requirements of their particular subsystem and corrective procedures which may be involved in repsonse to certain performance errors. They can control the functions of equipment in their system and coordinate system task schedules. On a higher level, the Executive contains knowledge of all resources, task schedules for all systems, and the relative priority of all resources and tasks. The executive can override any subsystem task schedule in order to resolve use conflicts or resolve errors that require resources from multiple subsystems. Interprocessor communication is implemented using the SAFTIES Communications Interface (SCI). The SCI is an application layer protocol which supports the SAFTIES distributed multi-level architecture. Author

N89-10096*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ADVANCED DATA MANAGEMENT DESIGN FOR AUTONOMOUS TELEROBOTIC SYSTEMS IN SPACE USING SPACEBORNE SYMBOLIC PROCESSORS
ANDRE GOFORTH *In* NASA, Goddard Space Flight Center, Proceedings of 1987 Goddard Conference on Space Applications of Artificial Intelligence (AI) and Robotics 19 p 1987
Avail: NTIS HC A99/MF E03 CSCL 09B

The use of computers in autonomous telerobots is reaching the point where advanced distributed processing concepts and techniques are needed to support the functioning of Space Station era telerobotic systems. Three major issues that have impact on the design of data management functions in a telerobot are covered. It also presents a design concept that incorporates an intelligent systems manager (ISM) running on a spaceborne symbolic processor (SSP), to address these issues. The first issue is the support of a system-wide control architecture or control philosophy. Salient features of two candidates are presented that impose constraints on data management design. The second issue is the role of data management in terms of system integration. This referes to providing shared or coordinated data processing and storage resources to a variety of telerobotic components such as vision, mechanical sensing, real-time coordinated multiple limb and end effector control, and planning and reasoning. The third issue is hardware that supports symbolic processing in conjunction with standard data I/O and numeric processing. A SSP that currently is seen to be technologically feasible and is being developed is described and used as a baseline in the design concept. Author

N89-10553*# Inference Corp., Los Angeles, CA.
SIMPLIFYING THE CONSTRUCTION OF DOMAIN-SPECIFIC AUTOMATIC PROGRAMMING SYSTEMS: THE NASA AUTOMATED SOFTWARE DEVELOPMENT WORKSTATION PROJECT
BRADLEY P. ALLEN and PETER L. HOLTZMAN *In* RADC, Second Annual Knowledge-Based Software Assistant Conference p 262-271 Jan. 1988 Previously announced as N88-17212
(Contract NAS9-17766)
Avail: NTIS HC A14/MF A01 CSCL 09B

An overview is presented of the Automated Software Development Workstation Project, an effort to explore knowledge-based approaches to increasing software productivity. The project focuses on applying the concept of domain specific automatic programming systems (D-SAPSs) to application domains at NASA's Johnson Space Flight Center. A version of a D-SAPS developed in Phase 1 of the project for the domain of space station momentum management is described. How problems encountered during its implementation led researchers to concentrate on simplifying the process of building and extending such systems is discussed. Researchers propose to do this by attacking three observed bottlenecks in the D-SAPS development process through the increased automation of the acquisition of programming knowledge and the use of an object oriented development methodology at all stages of the program design. How these ideas are being implemented in the Bauhaus, a prototype workstation for D-SAPS development is discussed.
Author

N89-12255# CISI Ingenierie, Toulouse (France).
STUDY OF THE DEVEOPMENT OF ON-BOARD DISTRIBUTED SOFTWARE SYSTEMS USING ADA
BERTRAND PORCHERLABREUILLE and ALBERTO DELLATORRE Paris, France ESA May 1988 71 p Prepared in cooperation with Carlo Gavazzi Controls S.p.A., Milan, Italy
(Contract ESA-6572/85-NL-PP)
(ESA-CR(P)-2651; ETN-88-93247) Avail: NTIS HC A04/MF A01

Use of Ada technology for the design and implementation of large distributed systems in the context of the Columbus space station program was assessed by developing in Ada a prototype of an on-board data management system (DMS). Results and lessons learnt by applying a virtual node approach together with hierarchical object oriented design contribute to a better understanding and management of the use of Ada technology. This approach provides the definition of a development framework very well adapted to the Columbus DMS context. By defining applications and services software as Ada virtual nodes it is possible to design the whole system as a single Ada program, structured according to the architecture adopted for DMS. The applications could be developed in parallel on geographically distributed sites and be validated individually using this initial model and the corresponding interface specification. The final integration process could concentrate on the operational validation of the system in distributed configuration (the functional validation in centralized configuration being obtained at the end of the first phase). The efficient implementation of this method requires support tools for: checking the rules imposed by the virtual node approach; and scanning virtual node specifications (Ada packages) in order to generate a surrogate software layer to provide syntactically transparent communication between virtual nodes located on distinct physical processors. ESA

N89-12397# National Aerospace Lab., Amsterdam (Netherlands). Informatics Div.
OPTICAL DATA STORAGE IN SPACE MISSIONS
L. J. M. JOOSTEN, R. M. M. SIJMONSMA, F. B. VISSER, and W. E. REESINK (Van der Heem Electronics N. V., Rijswijk, Netherlands)
20 Mar. 1987 21 p Presented at the Symposium on Technology and Standardization for On-Board Data Management Systems, Madrid, Spain, 1-5 Jun. 1987
(Contract NIVR-425-02602N)
(NLR-MP-87027-U; B8805846; ETN-88-93395; AD-B118878L)
Avail: NTIS HC A03/MF A01

Optical mass storage of digital data (CD-ROM, WORM) for use in space missions was assessed. Upgrading of commercial devices seems feasible, while ground support can be done by common equipment and software. ESA

N89-13299# National Oceanic and Atmospheric Administration, Boulder, CO. Space Environment Lab.
SPACE ENVIRONMENT LABORATORY DATA ACQUISITION AND DISPLAY SYSTEM 2
J. R. ABEYTA, C. C. BALCH, W. P. BARRETT, F. C. COWLEY, and C. M. CRUICKSHANK Mar. 1988 96 p
(PB88-205471; NOAA-TM-ERL-SEL-76) Avail: NTIS HC A05/MF A01 CSCL 05/2

The purpose of the publication is to document the effort undertaken by the staff of the Space Environment Laboratory to design and implement the Space Environment Laboratory Data Acquisition and Display System 2 (SELDADS 2). The information presented here is intended for a broad spectrum of readers, both management and technical, who may be involved with computer system design and implementation. SELDADS 2 is the second generation of dedicated computer support for the Space Environment Services Center operation. The first part of the report, describing the purpose and the history of the operation, is intended to provide the reader with a framework for understanding why and how SELDADS 2 came into existence. GRA

N89-13485# Aerospace Corp., El Segundo, CA. Space Sciences Lab.
SPACECRAFT ENVIRONMENTAL ANOMALIES EXPERT SYSTEM Status Report
H. C. KOONS and D. J. GORNEY 1 Dec. 1988 115 p
(AEROSPACE-ATR-88(9562)-1) Avail: NTIS HC A06/MF A01

A microcomputer based expert system is being developed to assist in the diagnosis of satellite anomalies caused by the space environment. The expert system is designed to address anomalies caused by surface charging, bulk charging, single event effects, and total radiation dose. These effects depend on the orbit of the satellite, the local environment (which is highly variable), the satellite exposure time, and the hardness of the circuits and components of the satellite. The expert system is a rule-based system that uses the Texas Instrument Personal Consultant Plus expert system shell. The completed expert system knowledge base will include 150 to 200 rules, as well as a spacecraft attributes database, a historical spacecraft anomalies database, and a space environment database which is updated in near real time. Currently, the expert system is undergoing development and testing. The status of the expert system development completed in FY88 is reviewed. Author

N89-14695*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ANALYSIS OF FDDI SYNCHRONOUS TRAFFIC DELAYS
MARJORY J. JOHNSON Jan. 1988 21 p
(Contract NCC2-387)
(NASA-CR-183223; RIACS-TR-88.3; NAS 1.26:183223) Avail: NTIS HC A03/MF A01 CSCL 09/2

The Fiber Distributed Data Interface (FDDI) high-speed token-ring protocol provides support for two classes of service: synchronous, to support applications which require deterministic access to the channel, and asynchronous, to support applications which do not have such stringent response-time requirements. The purpose of this paper is to determine how to set ring parameters to support synchronous traffic most efficiently. Both theoretical results and results obtained from a simulation study are presented. Author

N89-15550*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
CONSIDERATIONS IN DEVELOPMENT OF EXPERT SYSTEMS FOR REAL-TIME SPACE APPLICATIONS
S. MURUGESAN *In* NASA, Marshall Space Flight Center, Fourth Conference on Artificial Intelligence for Space Applications p 1-3

Oct. 1988
Avail: NTIS HC A21/MF A01 CSCL 09/2

Over the years demand on space systems have been increased tremendously and this trend will continue for the near future. The enhanced capabilities of space systems, however, can only be met with increased complexity and sophistication of onboard and ground systems, and artificial intelligence and expert system concepts have a significant role in space applications. Expert systems could facilitate decision making, improved fault diagnosis and repair, enhanced performance and less reliance on ground support. However, some requirements have to be fulfilled before practical use of flight-worthy expert systems for onboard (and ground) operations. This paper discusses some of the characteristics and important considerations in design, development, implementation and use of expert systems for real-life space applications. Further, it describes a typical life cycle of expert system development and its usage. Author

N89-15555*# Phase Linear Systems, Inc., Fairfax, VA.
KAM (KNOWLEDGE ACQUISITION MODULE): A TOOL TO SIMPLIFY THE KNOWLEDGE ACQUISITION PROCESS
GARY A. GETTIG *In* NASA, Marshall Space Flight Center, Fourth Confnce on Artificial Intelligence for Space Applications p 47-55 Oct. 1988
Avail: NTIS HC A21/MF A01 CSCL 05/2

Analysts, knowledge engineers and information specialists are faced with increasing volumes of time-sensitive data in text form, either as free text or highly structured text records. Rapid access to the relevant data in these sources is essential. However, due to the volume and organization of the contents, and limitations of human memory and association, frequently: (1) important information is not located in time; (2) reams of irrelevant data are searched; and (3) interesting or critical associations are missed due to physical or temporal gaps involved in working with large files. The Knowledge Acquisition Module (KAM) is a microcomputer-based expert system designed to assist knowledge engineers, analysts, and other specialists in extracting useful knowledge from large volumes of digitized text and text-based files. KAM formulates non-explicit, ambiguous, or vague relations, rules, and facts into a manageable and consistent formal code. A library of system rules or heuristics is maintained to control the extraction of rules, relations, assertions, and other patterns from the text. These heuristics can be added, deleted or customized by the user. The user can further control the extraction process with optional topic specifications. This allows the user to cluster extracts based on specific topics. Because KAM formalizes diverse knowledge, it can be used by a variety of expert systems and automated reasoning applications. KAM can also perform important roles in computer-assisted training and skill development. Current research efforts include the applicability of neural networks to aid in the extraction process and the conversion of these extracts into standard formats. Author

N89-15578*# Alabama Univ., Huntsville. Dept. of MIS/MSC.
A KNOWLEDGE-BASED DECISION SUPPORT SYSTEM FOR PAYLOAD SCHEDULING
RAJESH TYAGI and FAN T. TSENG *In* NASA, Marshall Space Flight Center, Fourth Conference on Artificial Intelligence for Space Applications p 207-210 Oct. 1988
Avail: NTIS HC A21/MF A01 CSCL 05/1

This paper presents the development of a prototype Knowledge-based Decision Support System, currently under development, for scheduling payloads/experiments on space station missions. The DSS is being built on Symbolics, a Lisp machine, using KEE, a commercial knowledge engineering tool. Author

N89-15586*# Sydney Univ. (Australia). Dept. of Computer Science.
DYNAMIC REASONING IN A KNOWLEDGE-BASED SYSTEM
ANAND S. RAO and NORMAN Y. FOO *In* NASA, Marshall Space Flight Center, Fourth Conference on Artificial Intelligence for Space Applications p 261-270 Oct. 1988
Avail: NTIS HC A21/MF A01 CSCL 09/2

Any space based system, whether it is a robot arm assembling parts in space or an onboard system monitoring the space station, has to react to changes which cannot be foreseen. As a result, apart from having domain-specific knowledge as in current expert systems, a space based AI system should also have general principles of change. This paper presents a modal logic which can not only represent change but also reason with it. Three primitive operations, expansion, contraction and revision are introduced and axioms which specify how the knowledge base should change when the external world changes are also specified. Accordingly the notion of dynamic reasoning is introduced, which unlike the existing forms of reasoning, provide general principles of change. Dynamic reasoning is based on two main principles, namely minimize change and maximize coherence. A possible-world semantics which incorporates the above two principles is also discussed. The paper concludes by discussing how the dynamic reasoning system can be used to specify actions and hence form an integral part of an autonomous reasoning and planning system. Author

N89-15587*# Missouri Univ., Rolla. Graduate Engineering Center.
STRATEGIES FOR ADDING ADAPTIVE LEARNING MECHANISMS TO RULE-BASED DIAGNOSTIC EXPERT SYSTEMS
D. C. STCLAIR, C. L. SABHARWAL, W. E. BOND, and KEITH HACKE (McDonnell-Douglas Research Labs., St. Louis, MO.) *In* NASA, Marshall Space Flight Center, Fourth Conference on Artificial Intelligence for Space Applications p 271-279 Oct. 1988
Avail: NTIS HC A21/MF A01 CSCL 09/2

Rule-based diagnostic expert systems can be used to perform many of the diagnostic chores necessary in today's complex space systems. These expert systems typically take a set of symptoms as input and produce diagnostic advice as output. The primary objective of such expert systems is to provide accurate and comprehensive advice which can be used to help return the space system in question to nominal operation. The development and maintenance of diagnostic expert systems is time and labor intensive since the services of both knowledge engineer(s) and domain expert(s) are required. The use of adaptive learning mechanisms to increment evaluate and refine rules promises to reduce both time and labor costs associated with such systems. This paper describes the basic adaptive learning mechanisms of strengthening, weakening, generalization, discrimination, and discovery. Next basic strategies are discussed for adding these learning mechanisms to rule-based diagnostic expert systems. These strategies support the incremental evaluation and refinement of rules in the knowledge base by comparing the set of advice given by the expert system (A) with the correct diagnosis (C). Techniques are described for selecting those rules in the in the knowledge base which should participate in adaptive learning. The strategies presented may be used with a wide variety of learning algorithms. Further, these strategies are applicable to a large number of rule-based diagnostic expert systems. They may be used to provide either immediate or deferred updating of the knowledge base. Author

N89-15598*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
PI-IN-A-BOX: INTELLIGENT ONBOARD ASSISTANCE FOR SPACEBORNE EXPERIMENTS IN VESTIBULAR PHYSIOLOGY
SILVANO COLOMBANO, LAURENCE YOUNG, NANCY WOGRIN (Stanford Univ., CA.), and DON ROSENTHAL *In* NASA, Marshall Space Flight Center, Fourth Conference on Artificial Intelligence for Space Applications p 371-380 Oct. 1988 Prepared in cooperation with Digital Equipment Corp., Palo Alto, CA
Avail: NTIS HC A21/MF A01 CSCL 09/2

In construction is a knowledge-based system that will aid astronauts in the performance of vestibular experiments in two ways: it will provide real-time monitoring and control of signals and it will optimize the quality of the data obtained, by helping

the mission specialists and payload specialists make decisions that are normally the province of a principal investigator, hence the name PI-in-a-box. An important and desirable side-effect of this tool will be to make the astronauts more productive and better integrated members of the scientific team. The vestibular experiments are planned by Prof. Larry Young of MIT, whose team has already performed similar experiments in Spacelab missions SL-1 and D-1, and has experiments planned for SLS-1 and SLS-2. The knowledge-based system development work, performed in collaboration with MIT, Stanford University, and the NASA-Ames Research Center, addresses six major related functions: (1) signal quality monitoring; (2) fault diagnosis; (3) signal analysis; (4) interesting-case detection; (5) experiment replanning; and (6) integration of all of these functions within a real-time data acquisition environment. Initial prototyping work has been done in functions (1) through (4). Author

N89-15602*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ADA IN AI OR AI IN ADA. ON DEVELOPING A RATIONALE FOR INTEGRATION
PHILIPPE E. COLLARD (California Univ., San Diego, La Jolla.) and ANDRE GOFORTH *In* NASA, Marshall Space Flight Center, Fourth Conference on Artificial Intelligence for Space Applications p 411-419 Oct. 1988
Avail: NTIS HC A21/MF A01 CSCL 09/2

The use of Ada as an Artificial Intelligence (AI) language is gaining interest in the NASA Community, i.e., by parties who have a need to deploy Knowledge Based-Systems (KBS) compatible with the use of Ada as the software standard for the Space Station. A fair number of KBS and pseudo-KBS implementations in Ada exist today. Currently, no widely used guidelines exist to compare and evaluate these with one another. The lack of guidelines illustrates a fundamental problem inherent in trying to compare and evaluate implementations of any sort in languages that are procedural or imperative in style, such as Ada, with those in languages that are functional in style, such as Lisp. Discussed are the strengths and weakness of using Ada as an AI language and a preliminary analysis provided of factors needed for the development of criteria for the integration of these two families of languages and the environments in which they are implemented. The intent for developing such criteria is to have a logical rationale that may be used to guide the development of Ada tools and methodology to support KBS requirements, and to identify those AI technology components that may most readily and effectively be deployed in Ada. Author

N89-15631*# Computer Sciences Corp., Hampton, VA.
FLEXAN (VERSION 2.0) USER'S GUIDE
SCOTT S. STALLCUP Washington, DC Jan. 1989 41 p
(Contract NAS1-17999)
(NASA-CR-4214; NAS 1.26:4214; TAO-50287) Avail: NTIS HC A03/MF A01 CSCL 09/2

The FLEXAN (Flexible Animation) computer program, Version 2.0 is described. FLEXAN animates 3-D wireframe structural dynamics on the Evans and Sutherland PS300 graphics workstation with a VAX/VMS host computer. Animation options include: unconstrained vibrational modes, mode time histories (multiple modes), delta time histories (modal and/or nonmodal deformations), color time histories (elements of the structure change colors through time), and rotational time histories (parts of the structure rotate through time). Concurrent color, mode, delta, and rotation, time history animations are supported. FLEXAN does not model structures or calculate the dynamics of structures; it only animates data from other computer programs. FLEXAN was developed to aid in the study of the structural dynamics of spacecraft. Author

N89-16279*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
FIRST INTERNATIONAL CONFERENCE ON ADA (R) PROGRAMMING LANGUAGE APPLICATIONS FOR THE NASA SPACE STATION, VOLUME 1
RODNEY L. BOWN, ed. 1986 420 p Conference held in Houston, TX, 2-5 Jun. 1986 Prepared in cooperation with Houston Univ., Clear Lake, TX
(Contract NAS9-17010)
(NASA-TM-101201; NAS 1.15:101201) Avail: NTIS HC A18/MF A01 CSCL 09/2

Topics discussed include: test and verification; environment issues; distributed Ada issues; life cycle issues; Ada in Europe; management/training issues; common Ada interface set; and run time issues.

N89-16280*# Virginia Polytechnic Inst. and State Univ., Blacksburg.
DEBUGGING TASKED ADA PROGRAMS
R. G. FAINTER and T. E. LINDQUIST (Arizona State Univ., Tempe.) *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 1 23 p 1986
Avail: NTIS HC A18/MF A01 CSCL 09/2

The applications for which Ada was developed require distributed implementations of the language and extensive use of tasking facilities. Debugging and testing technology as it applies to parallel features of languages currently falls short of needs. Thus, the development of embedded systems using Ada pose special challenges to the software engineer. Techniques for distributing Ada programs, support for simulating distributed target machines, testing facilities for tasked programs, and debugging support applicable to simulated and to real targets all need to be addressed. A technique is presented for debugging Ada programs that use tasking and it describes a debugger, called AdaTAD, to support the technique. The debugging technique is presented together with the use interface to AdaTAD. The component of AdaTAD that monitors and controls communication among tasks was designed in Ada and is presented through an example with a simple tasked program. Author

N89-16283*# General Research Corp., Santa Barbara, CA.
ADA(R) TEST AND VERIFICATION SYSTEM (ATVS)
TOM STRELICH *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 1 10 p 1986
(Contract F30602-84-C-0118)
Avail: NTIS HC A18/MF A01 CSCL 09/2

The Ada Test and Verification System (ATVS) functional description and high level design are completed and summarized. The ATVS will provide a comprehensive set of test and verification capabilities specifically addressing the features of the Ada language, support for embedded system development, distributed environments, and advanced user interface capabilities. Its design emphasis was on effective software development environment integration and flexibility to ensure its long-term use in the Ada software development community. B.G.

N89-16284*# Softech, Inc., Blue Bell, PA.
THE TESTABILITY OF ADA PROGRAMS
DAVID AUTY and NORMAN H. COHEN *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 1 7 p 1986
Avail: NTIS HC A18/MF A01 CSCL 09/2

Software development for NASA's Space Station poses a significant problem; considered the most difficult by some. The difficulty is the magnitude and complexity of the required software. The concerns raised by consideration of the requirements for testing and checkout procedures for the Space Station software are addressed. In particular, it addresses the use of Ada in the development of widely distributed yet closely coordinated processing. Author

N89-16290*# Rational, Mountain View, CA.
RATIONAL'S EXPERIENCE USING ADA FOR VERY LARGE SYSTEMS
JAMES E. ARCHER, JR. and MICHAEL T. DEVLIN *In* NASA,

Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 1 12 p 1986
Avail: NTIS HC A18/MF A01 CSCL 09/2

The experience using the Rational Environment has confirmed the advantages forseen when the project was started. Interactive syntatic and semantic information makes a tremendous difference in the ease of constructing programs and making changes to them. The ability to follow semantic references makes it easier to understand exisiting programs and the impact of changes. The integrated debugger makes it much easier to find bugs and test fixes quickly. Taken together, these facilites have helped greatly in reducing the impact of ongoing maintenance of the ability to produce a new code. Similar improvements are anticipated as the same level of integration and interactivity are achieved for configuration management and version control. The environment has also proven useful in introducing personnel to the project and existing personnel to new parts of the system. Personnel benefit from the assistance with syntax and semantics; everyone benefits from the ability to traverse and understand the structure of unfamiliar software. It is often possible for someone completely unfamiliar with a body of code to use these facilities, to understand it well enough to successfully with a body of code to use these facilities to understand it well enough to successfully diagnose and fix bugs in a matter of minutes. Author

N89-16291*# Alsys, Inc., Waltham, MA.
USING ADA (R) ON A WORKSTATION FOR LARGE PROJECTS Abstract Only
ARRA S. AVAKIAN, BENJAMIN M. BROSGOL, and MITCHELL GART *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 1 2 p 1986
Avail: NTIS HC A18/MF A01 CSCL 09/2

Alsys has implemented validated Ada compilers that are hosted and targeted on a variety of microprocessor-based workstations, including the IBM PC/AT. The availability of Ada compilers for these kinds of inexpensive, widely available machines considerably enhances the development options for large efforts such as the NASA Space Station, and this is addressed from both an implementation and a user perspective. First, the issue of large program development on a workstation is discussed: how the compiler must handle this, and how an inherently decentralized approach can be managed. Next, the focus is on code efficiency and the compiler and run-time design decisions that help meet this goal are described. It is concluded with a presentation of benchmarks that are quite encouraging with respect to the run-time efficiency of Ada code compared with other languages. Author

N89-16299*# Systems Technology, Lawrence, KS.
ANALYSIS AND SPECIFICATION TOOLS IN RELATION TO THE APSE
JOHN W. HENDRICKS *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 1 10 p 1986
Avail: NTIS HC A18/MF A01 CSCL 09/2

Ada and the Ada Programming Support Environment (APSE) specifically address the phases of the system/software life cycle which follow after the user's problem was translated into system and software development specifications. The waterfall model of the life cycle identifies the analysis and requirements definition phases as preceeding program design and coding. Since Ada is a programming language and the APSE is a programming support environment, they are primarily targeted to support program (code) development, tecting, and maintenance. The use of Ada based or Ada related specification languages (SLs) and program design languages (PDLs) can extend the use of Ada back into the software design phases of the life cycle. Recall that the standardization of the APSE as a programming support environment is only now happening after many years of evolutionary experience with diverse sets of programming support tools. Restricting consideration to one, or even a few chosen specification and design tools, could be a real mistake for an organization or a major project such as the Space Station, which will need to deal with an increasingly complex level of system problems. To require that everything be Ada-like, be implemented in Ada, run directly under the APSE, and fit into a rigid waterfall model of the life cycle would turn a promising support environment into a straight jacket for progress. Author

N89-16301*# Mitre Corp., Bedford, MA.
A COMPUTER-BASED SPECIFICATION METHODOLOGY
ROBERT G. MUNCK *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 1 7 p 1986
Avail: NTIS HC A18/MF A01 CSCL 09/2

Standard practices for creating and using system specifications are inadequate for large, advanced-technology systems. A need exists to break away from paper documents in favor of documents that are stored in computers and which are read and otherwise used with the help of computers. An SADT-based system, running on the proposed Space Station data management network, could be a powerful tool for doing much of the required technical work of the Station, including creating and operating the network itself. Author

N89-16304*# McDonnell-Douglas Astronautics Co., Houston, TX.
A PROPOSED CLASSIFICATION SCHEME FOR ADA-BASED SOFTWARE PRODUCTS
GARY J. CERNOSEK *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 1 8 p 1986
Avail: NTIS HC A18/MF A01 CSCL 09/2

As the requirements for producing software in the Ada language become a reality for projects such as the Space Station, a great amount of Ada-based program code will begin to emerge. Recognizing the potential for varying levels of quality to result in Ada programs, what is needed is a classification scheme that describes the quality of a software product whose source code exists in Ada form. A 5-level classification scheme is proposed that attempts to decompose this potentially broad spectrum of quality which Ada programs may possess. The number of classes and their corresponding names are not as important as the mere fact that there needs to be some set of criteria from which to evaluate programs existing in Ada. An exact criteria for each class is not presented, nor are any detailed suggestions of how to effectively implement this quality assessment. The idea of Ada-based software classification is introduced and a set of requirements from which to base further research and development is suggested. Author

N89-16305*# Informatique Internationale S.A., Toulouse (France).
ADA (R) ASSESSMENT: AN IMPORTANT ISSUE WITHIN EUROPEAN COLUMBUS SUPPORT TECHNOLOGY PROGRAMME
P. VIELCANET *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 1 8 p 1986
Avail: NTIS HC A18/MF A01 CSCL 09/2

Software will be more important and more critical for Columbus than for any ESA previous project. As a simple comparison, overall software size has been in the range of 100 K source statements for EXOSAT, 500 K for Spacelab, and will probably reach several million lines of code for Columbus (all element together). Based on past experience, the total development cost of software can account for about 10 pct to 15 pct of the total space project development cost. The Ada technology may support the strong software engineering principles needed for Columbus, provided that technology is sufficiently mature and industry plans are meeting the Columbus project schedule. Over the past 3 years, Informatique Internationale has conducted a coherent program based on Ada technology assessment studies and experiments, for ESA and CNES. This specific research and development program benefits

from 15 years experience in the field of space software development and is supported by the overall software engineering expertise of the company. The assessment and experiments of Ada software engineering by Informatique Internationale are detailed. Author

N89-16311*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
GSFC ADA PROGRAMMING GUIDELINES
DANIEL M. ROY (Century Computing, Inc., Laurel, MD.) and ROBERT W. NELSON *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 1 10 p 1986
Avail: NTIS HC A18/MF A01 CSCL 09/2

A significant Ada effort has been under way at Goddard for the last two years. To ease the center's transition toward Ada (notably for future space station projects), a cooperative effort of half a dozen companies and NASA personnel was started in 1985 to produce programming standards and guidelines for the Ada language. The great richness of the Ada language and the need of programmers for good style examples makes Ada programming guidelines an important tool to smooth the Ada transition. Because of the natural divergence of technical opinions, the great diversity of our government and private organizations and the novelty of the Ada technology, the creation of an Ada programming guidelines document is a difficult and time consuming task. It is also a vital one. Steps must now be taken to ensure that the guide is refined in an organized but timely manner to reflect the growing level of expertise of the Ada community. Author

N89-16314*# George Mason Univ., Fairfax, VA.
THE IMPACT OF COMMON APSE INTERFACE SET SPECIFICATIONS ON SPACE STATION INFORMATION SYSTEMS
JORGE L. DIAZ-HERRERA and EDGAR H. SIBLEY *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 1 11 p 1986
Avail: NTIS HC A18/MF A01 CSCL 09/2

Certain types of software facilities are needed in a Space Station Information Systems Environment; the Common APSE (Ada Program Support Environment) Interface Set (CAIS) was proposed as a means of satisfying them. The reasonableness of this is discussed by examining the current CAIS, considering the changes due to the latest Requirements and Criteria (RAC) document, and postulating the effects on the CAIS 2.0. Finally, a few additional comments are made on the problems inherent in the Ada language itself, especially on its deficiencies when used for implementing large distributed processing and data base applications. Author

N89-16315*# TRW Defense Systems Group, Redondo Beach, CA.
A RISK MANAGEMENT APPROACH TO CAIS DEVELOPMENT
HAL HART, JUDY KERNER, TONY ALDEN, FRANK BELZ, and FRANK TADMAN *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 1 6 p 1986
Avail: NTIS HC A18/MF A01 CSCL 09/2

The proposed DoD standard Common APSE Interface Set (CAIS) was developed as a framework set of interfaces that will support the transportability and interoperability of tools in the support environments of the future. While the current CAIS version is a promising start toward fulfilling those goals and current prototypes provide adequate testbeds for investigations in support of completing specifications for a full CAIS, there are many reasons why the proposed CAIS might fail to become a usable product and the foundation of next-generation (1990'S) project support environments such as NASA's Space Station software support environment. The most critical threats to the viability and acceptance of the CAIS include performance issues (especially in piggybacked implementations), transportability, and security requirements. To make the situation worse, the solution to some of these threats appears to be at conflict with the solutions to others. Author

N89-16318*# Softech, Inc., Houston, TX.
THE CAIS 2 PROJECT
SUE LEGRAND and RICHARD THALL (Softech, Inc., Waltham, MA.) *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 1 6 p 1986
Avail: NTIS HC A18/MF A01 CSCL 09/2

The Common APSE Interface Set (CAIS) is a proposed MIL-STD intended to promote the portability of Ada Programming Support Environment (APSE) tools written in Ada. The standardized interfaces define a virtual operating system, from which portable tools derive their basic services, e.g., file management, input/output, communications, and process control. In the Ada world, such a virtual operating system is called a Kernel Ada Programming Support Environment (KAPSE). The CAIS is a standardized interface between KAPSEs and tools. The CAIS has been proposed as a starting point for standard interfaces to be used in the NASA Software Support Environment (SSE) for the Space Station Program. The status of the CAIS standardization effort and plans for further development are described. Author

N89-16319*# Planning Research Corp., McLean, VA.
TRANSPORTABILITY, DISTRIBUTABILITY AND REHOSTING EXPERIENCE WITH A KERNEL OPERATING SYSTEM INTERFACE SET
F. C. BLUMBERG, A. REEDY, and E. YODIS *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 1 14 p 1986
Avail: NTIS HC A18/MF A01 CSCL 09/2

For the past two years, PRC has been transporting and installing a software engineering environment framework, the Automated Product control Environment (APCE), at a number of PRC and government sites on a variety of different hardware. The APCE was designed using a layered architecture which is based on a standardized set of interfaces to host system services. This interface set called the APCE Interface Set (AIS), was designed to support many of the same goals as the Common Ada Programming Support Environment (APSE) Interface Set (CAIS). The APCE was developed to provide support for the full software lifecycle. Specific requirements of the APCE design included: automation of labor intensive administrative and logistical tasks: freedom for project team members to use existing tools: maximum transportability for APCE programs, interoperability of APCE database data, and distributability of both processes and data: and maximum performance on a wide variety of operating systems. A brief description is given of the APCE and AIS, a comparison of the AIS and CAIS both in terms of functionality and of philosophy and approach and a presentation of PRC's experience in rehosting AIS and transporting APCE programs and project data. Conclusions are drawn from this experience with respect to both the CAIS efforts and Space Station plans. Author

N89-16320*# Research Triangle Inst., Research Triangle Park, NC.
CONSTRUCTING A WORKING TAXONOMY OF FUNCTIONAL ADA SOFTWARE COMPONENTS FOR REAL-TIME EMBEDDED SYSTEM APPLICATIONS Abstract Only
ROBERT WALLACE *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 1 1 p 1986
Avail: NTIS HC A18/MF A01 CSCL 09/2

A major impediment to a systematic attack on Ada software reusability is the lack of an effective taxonomy for software component functions. The scope of all possible applications of Ada software is considered too great to allow the practical development of a working taxonomy. Instead, for the purposes herein, the scope of Ada software application is limited to device and subsystem control in real-time embedded systems. A functional

approach is taken in constructing the taxonomy tree for identified Ada domain. The use of modular software functions as a starting point fits well with the object oriented programming philosophy of Ada. Examples of the types of functions represented within the working taxonomy are real time kernels, interrupt service routines, synchronization and message passing, data conversion, digital filtering and signal conditioning, and device control. The constructed taxonomy is proposed as a framework from which a need analysis can be performed to reveal voids in current Ada real-time embedded programming efforts for Space Station. Author

N89-16326*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
FIRST INTERNATIONAL CONFERENCE ON ADA (R) PROGRAMMING LANGUAGE APPLICATIONS FOR THE NASA SPACE STATION, VOLUME 2
RODNEY L. BOWN, ed. 1986 504 p Conference held in Houston, TX, 2-5 Jun. 1986 Prepared in cooperation with Houston Univ., Clear Lake, TX
(Contract NAS9-17010)
(NASA-TM-101202; NAS 1.15:101202) Avail: NTIS HC A22/MF A01 CSCL 09/2

Topics discussed include: reusability; mission critical issues; run time; expert systems; language issues; life cycle issues; software tools; and computers for Ada.

N89-16331*# Productivity Research Corp., Cape Canaveral, FL.
SOME DESIGN CONSTRAINTS REQUIRED FOR THE ASSEMBLY OF SOFTWARE COMPONENTS: THE INCORPORATION OF ATOMIC ABSTRACT TYPES INTO GENERICALLY STRUCTURED ABSTRACT TYPES
CHARLES S. JOHNSON *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 12 p 1986
Avail: NTIS HC A22/MF A01 CSCL 09/2

It is nearly axiomatic, that to take the greatest advantage of the useful features available in a development system, and to avoid the negative interactions of those features, requires the exercise of a design methodology which constrains their use. A major design support feature of the Ada language is abstraction: for data, functions processes, resources, and system elements in general. Atomic abstract types can be created in packages defining those private types and all of the overloaded operators, functions, and hidden data required for their use in an application. Generically structured abstract types can be created in generic packages defining those structured private types, as buildups from the user-defined data types which are input as parameters. A study is made of the design constraints required for software incorporating either atomic or generically structured abstract types, if the integration of software components based on them is to be subsequently performed. The impact of these techniques on the reusability of software and the creation of project-specific software support environments is also discussed. Author

N89-16337*# Carnegie-Mellon Univ., Pittsburgh, PA. Software Engineering Inst.
LESSONS LEARNED IN CREATING SPACECRAFT COMPUTER SYSTEMS: IMPLICATIONS FOR USING ADA (R) FOR THE SPACE STATION
JAMES E. TOMAYKO *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 11 p 1986 Sponsored in part by DOD, Washington, D.C.
(Contract NASW-3714)
Avail: NTIS HC A22/MF A01 CSCL 09/2

Twenty-five years of spacecraft onboard computer development have resulted in a better understanding of the requirements for effective, efficient, and fault tolerant flight computer systems. Lessons from eight flight programs (Gemini, Apollo, Skylab, Shuttle, Mariner, Voyager, and Galileo) and three reserach programs (digital fly-by-wire, STAR, and the Unified Data System) are useful in projecting the computer hardware configuration of the Space Station and the ways in which the Ada programming language will enhance the development of the necessary software. The evolution of hardware technology, fault protection methods, and software architectures used in space flight in order to provide insight into the pending development of such items for the Space Station are reviewed. Author

N89-16341*# Veda, Inc., Lexington Park, MD.
GENERIC ADA CODE IN THE NASA SPACE STATION COMMAND, CONTROL AND COMMUNICATIONS ENVIRONMENT
D. P. MCDOUGALL and T. E. VOLLMAN *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 13 p 1986
Avail: NTIS HC A22/MF A01 CSCL 09/2

The results of efforts to apply powerful Ada constructs to the formatted message handling process are described. The goal of these efforts was to extend the state-of-technology in message handling while at the same time producing production-quality, reusable code. The first effort was initiated in September, 1984 and delivered in April, 1985. That product, the Generic Message Handling Facility, met initial goals, was reused, and is available in the Ada Repository on ARPANET. However, it became apparent during its development that the initial approach to building a message handler template was not optimal. As a result of this initial effort, several alternate approaches were identified, and research is now on-going to identify an improved product. The ultimate goal is to be able to instantly build a message handling system for any message format given a specification of that message format. The problem lies in how to specify the message format, and one that is done, how to use that information to build the message handler. Message handling systems and message types are described. The initial efforts, its results and its shortcomings are detailed. The approach now being taken to build a system which will be significantly easier to implement, and once implemented, easier to use, is described. Finally, conclusions are offered. Author

N89-16346*# Saab Space A.B., Goeteborg (Sweden).
INTERESTING VIEWPOINTS TO THOSE WHO WILL PUT ADA INTO PRACTICE
ARNE CARLSSON *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 11 p 1986
Avail: NTIS HC A22/MF A01 CSCL 09/2

Ada will most probably be used as the programming language for computers in the NASA Space Station. It is reasonable to suppose that Ada will be used for at least embedded computers, because the high software costs for these embedded computers were the reason why Ada activities were initiated about ten years ago. The on-board computers are designed for use in space applications, where maintenance by man is impossible. All manipulation of such computers has to be performed in an autonomous way or remote with commands from the ground. In a manned Space Station some maintenance work can be performed by service people on board, but there are still a lot of applications, which require autonomous computers, for example, vital Space Station functions and unmanned orbital transfer vehicles. Those aspect which have come out of the analysis of Ada characteristics together with the experience of requirements for embedded on-board computers in space applications are examined. Author

N89-16349*# Software Productivity Solutions, Inc., Melbourne, FL.
INTELLIGENT USER INTERFACE CONCEPT FOR SPACE STATION
EDWARD COMER, CAMERON DONALDSON, ELIZABETH BAILEY (Software Metrics, Inc.), and KATHLEEN GILROY *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 12 p 1986
Avail: NTIS HC A22/MF A01 CSCL 09/2

The space station computing system must interface with a wide variety of users, from highly skilled operations personnel to payload specialists from all over the world. The interface must accommodate a wide variety of operations from the space platform, ground control centers and from remote sites. As a result, there is a need for a robust, highly configurable and portable user interface that can accommodate the various space station missions. The concept of an intelligent user interface executive, written in Ada, that would support a number of advanced human interaction techniques, such as windowing, icons, color graphics, animation, and natural language processing is presented. The user interface would provide intelligent interaction by understanding the various user roles, the operations and mission, the current state of the environment and the current working context of the users. In addition, the intelligent user interface executive must be supported by a set of tools that would allow the executive to be easily configured and to allow rapid prototyping of proposed user dialogs. This capability would allow human engineering specialists acting in the role of dialog authors to define and validate various user scenarios. The set of tools required to support development of this intelligent human interface capability is discussed and the prototyping and validation efforts required for development of the Space Station's user interface are outlined. Author

N89-16350*# Ford Aerospace and Communications Corp., College Park, MD.
AN ADA INFERENCE ENGINE FOR EXPERT SYSTEMS
DAVID B. LAVALLEE *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 12 p 1986
Avail: NTIS HC A22/MF A01 CSCL 09/2

The purpose is to investigate the feasibility of using Ada for rule-based expert systems with real-time performance requirements. This includes exploring the Ada features which give improved performance to expert systems as well as optimizing the tradeoffs or workarounds that the use of Ada may require. A prototype inference engine was built using Ada, and rule firing rates in excess of 500 per second were demonstrated on a single MC68000 processor. The knowledge base uses a directed acyclic graph to represent production lines. The graph allows the use of AND, OR, and NOT logical operators. The inference engine uses a combination of both forward and backward chaining in order to reach goals as quickly as possible. Future efforts will include additional investigation of multiprocessing to improve performance and creating a user interface allowing rule input in an Ada-like syntax. Investigation of multitasking and alternate knowledge base representations will help to analyze some of the performance issues as they relate to larger problems. Author

N89-16351*# Sirius, Inc., Virginia Beach, VA.
AN APPROACH TO KNOWLEDGE STRUCTURING FOR ADVANCED PHASES OF THE TECHNICAL AND MANAGEMENT INFORMATION SYSTEM (TMIS)
H. T. GORANSON *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 8 p 1986
Avail: NTIS HC A22/MF A01 CSCL 09/2

The Technical and Management Information System (TMIS) must employ on enlightened approach to its object structure, but basic issues in conceptual structuring remain to be resolved. Sirius outlines the necessary agenda and reports on progress toward solutions. Author

N89-16352*# McDonnell-Douglas Astronautics Co., Huntington Beach, CA.
ADA AND KNOWLEDGE-BASED SYSTEMS: A PROTOTYPE COMBINING THE BEST OF BOTH WORLDS Abstract Only
DAVID C. BRAUER *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 1 p 1986
Avail: NTIS HC A22/MF A01 CSCL 09/2

A software architecture is described which facilitates the construction of distributed expert systems using Ada and selected knowledge based systems. This architecture was utilized in the development of a Knowledge-based Maintenance Expert System (KNOMES) prototype for the Space Station Mobile Service Center (MSC). The KNOMES prototype monitors a simulated data stream from MSC sensors and built-in test equipment. It detects anomalies in the data and performs diagnosis to determine the cause. The software architecture which supports the KNOMES prototype allows for the monitoring and diagnosis tasks to be performed concurrently. The basic concept of this software architecture is named ACTOR (Ada Cognitive Task ORganization Scheme). An individual ACTOR is a modular software unit which contains both standard data processing and artificial intelligence components. A generic ACTOR module contains Ada packages for communicating with other ACTORs and accessing various data sources. The knowledge based component of an ACTOR determines the role it will play in a system. In this prototype, an ACTOR will monitor the MSC data stream. Author

N89-16353*# McDonnell-Douglas Astronautics Co., Huntington Beach, CA.
USING ADA TO IMPLEMENT THE OPERATIONS MANAGEMENT SYSTEM IN A COMMUNITY OF EXPERTS
M. S. FRANK *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 2 p 1986
Avail: NTIS HC A22/MF A01 CSCL 09/2

An architecture is described for the Space Station Operations Management System (OMS), consisting of a distributed expert system framework implemented in Ada. The motivation for such a scheme is based on the desire to integrate the very diverse elements of the OMS while taking maximum advantage of knowledge based systems technology. Part of the foundation of an Ada based distributed expert system was accomplished in the form of a proof of concept prototype for the KNOMES project (Knowledge-based Maintenance Expert System). This prototype successfully used concurrently active experts to accomplish monitoring and diagnosis for the Remote Manipulator System. The basic concept of this software architecture is named ACTORS for Ada Cognitive Task ORganization Scheme. It is when one considers the overall problem of integrating all of the OMS elements into a cooperative system that the AI solution stands out. By utilizing a distributed knowledge based system as the framework for OMS, it is possible to integrate those components which need to share information in an intelligent manner. Author

N89-16355*# Ford Aerospace and Communications Corp., College Park, MD.
SIMULATION OF THE SPACE STATION INFORMATION SYSTEM IN ADA
JAMES R. SPIEGEL *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 10 p 1986
Avail: NTIS HC A22/MF A01 CSCL 09/2

The Flexible Ada Simulation Tool (FAST) is a discrete event simulation language which is written in Ada. FAST has been used to simulate a number of options for ground data distribution of Space Station payload data. The fact that Ada language is used for implementation has allowed a number of useful interactive features to be built into FAST and has facilitated quick enhancement of its capabilities to support new modeling requirements. General simulation concepts are discussed, and how these concepts are implemented in FAST. The FAST design is discussed, and it is pointed out how the used of the Ada language enabled the development of some significant advantages over classical FORTRAN based simulation languages. The advantages discussed are in the areas of efficiency, ease of debugging, and ease of integrating user code. The specific Ada language features which enable these advances are discussed. Author

N89-16361*# Package Architects, Inc., La Jolla, CA.
PARANOIA.ADA: A DIAGNOSTIC PROGRAM TO EVALUATE ADA FLOATING-POINT ARITHMETIC
CHRIS HJERMSTAD *In* NASA, Lyndon B. Johnson Space Center,

First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 13 p 1986
Avail: NTIS HC A22/MF A01 CSCL 09/2

Many essential software functions in the mission critical computer resource application domain depend on floating point arithmetic. Numerically intensive functions associated with the Space Station project, such as emphemeris generation or the implementation of Kalman filters, are likely to employ the floating point facilities of Ada. Paranoia.Ada appears to be a valuabe program to insure that Ada environments and their underlying hardware exhibit the precision and correctness required to satisfy mission computational requirements. As a diagnostic tool, Paranoia.Ada reveals many essential characteristics of an Ada floating point implementation. Equipped with such knowledge, programmers need not tremble before the complex task of floating point computation. Author

N89-16366*# Lockheed Missiles and Space Co., Burbank, CA.
THE TAVERNS EMULATOR: AN ADA SIMULATION OF THE SPACE STATION DATA COMMUNICATIONS NETWORK AND SOFTWARE DEVELOPMENT ENVIRONMENT
NORMAN R. HOWES *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 10 p 1986
Avail: NTIS HC A22/MF A01 CSCL 09/2

The Space Station DMS (Data Management System) is the onboard component of the Space Station Information System (SSIS) that includes the computers, networks and software that support the various core and payload subsystems of the Space Station. TAVERNS (Test And Validation Environment for Remote Networked Systems) is a distributed approach for development and validation of application software for Space Station. The TAVERNS concept assumes that the different subsystems will be developed by different contractors who may be geographically separated. The TAVERNS Emulator is an Ada simulation of a TAVERNS on the ASD VAX. The software services described in the DMS Test Bed User's Manual are being emulated on the VAX together with simulations of some of the core subsystems and a simulation of the DCN. The TAVERNS Emulator will be accessible remotely from any VAX that can communicate with the ASD VAX. Author

N89-16372*# Softech, Inc., Alexandria, VA.
A STUDY OF MAPSE EXTENSIONS
DAVID AUTY, ROBERT CHARETTE, and CHARLES W. MCKAY (Houston Univ., Clear Lake, TX.) *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 11 p 1986
Avail: NTIS HC A22/MF A01 CSCL 09/2

The technical issues of extending the Minimal Ada Programming Support Environment (MAPSE) to support the life cycle of large, complex distributed systems such as the Space Station Program (SSP) are studied. The work has been divided into two phases, Phase one, covered herein, identifies a list of advanced technical tools needed to extend the MAPSE to meet the needs believed to be inherent in the Software Support Environment (SSE). The description of SSE requirements are given, and a list of the tools are identified. An outline is also given of the principle requirements for a MAPSE, along with a description of the life cycle model and a description of the tools in the context of the life cycle model. Author

N89-16373*# Computer Sciences Corp., El Segundo, CA. Applied Technology Div.
ADA STRUCTURE DESIGN LANGUAGE (ASDL)
LUTFI CHEDRAWI *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 10 p 1986
Avail: NTIS HC A22/MF A01 CSCL 09/2

An artist acquires all the necessary tools before painting a scene. In the same analogy, a software engineer needs the necessary tools to provide their design with the proper means for implementation. Ada provide these tools. Yet, as an artist's painting needs a brochure to accompany it for further explanation of the scene, an Ada design also needs a document along with it to show the design in its detailed structure and hierarchical order. Ada could be self-explanatory in small programs not exceeding fifty lines of code in length. But, in a large environment, ranging from thousands of lines and above, Ada programs need to be well documented to be preserved and maintained. The language used to specify an Ada document is called Ada Structure Design Language (ASDL). This language sets some rules to help derive a well formatted Ada detailed design document. The rules are defined to meet the needs of a project manager, a maintenance team, a programmer and a systems designer. The design document templates, the document extractor, and the rules set forth by the ASDL are explained in detail. Author

N89-16374*# Rockwell Shuttle Operations Co., Houston, TX.
ARTIFICIAL INTELLIGENCE AND THE SPACE STATION SOFTWARE SUPPORT ENVIRONMENT
GILBERT MARLOWE *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 11 p 1986
Avail: NTIS HC A22/MF A01 CSCL 09/2

In a software system the size of the Space Station Software Support Environment (SSE), no one software development or implementation methodology is presently powerful enough to provide safe, reliable, maintainable, cost effective real time or near real time software. In an environment that must survive one of the most harsh and long life times, software must be produced that will perform as predicted, from the first time it is executed to the last. Many of the software challenges that will be faced will require strategies borrowed from Artificial Intelligence (AI). AI is the only development area mentioned as an example of a legitimate reason for a waiver from the overall requirement to use the Ada programming language for software development. The limits are defined of the applicability of the Ada language Ada Programming Support Environment (of which the SSE is a special case), and software engineering to AI solutions by describing a scenario that involves many facets of AI methodologies. Author

N89-16375*# McDonnell-Douglas Astronautics Co., Houston, TX.
SPACE STATION ADA RUNTIME SUPPORT FOR NESTED ATOMIC TRANSACTIONS Abstract Only
EDWARD J. MONTEIRO *In* NASA, Lyndon B. Johnson Space Center, First International Conference on Ada (R) Programming Language Applications for the NASA Space Station, Volume 2 1 p 1986
Avail: NTIS HC A22/MF A01 CSCL 09/2

The Space Station Data Management System (DMS), associated computing subsystems, and applications have varying degrees of reliability associated with their operation. A model has been developed (McKay '86) which allows the DMS runtime environment to appear as an Ada virtual machine to applications executing within it. This model is modular, flexible, and dynamically configurable to allow for evolution and growth over time. Support for Fault-tolerant computing is included within this model. The basic primitive involved in this support is based on atomic actions (Grey '78). An atomic action possesses two fundamental properties: (1) it is indivisible with respect to concurrent actions, and (2) it is indivisible with respect to failure. A transaction is a collection of atomic actions which collectively appear to be one action. Transactions may be nested, providing even more powerful support for reliability. A proposed approach is described for providing support for nested atomic transactions within the Ada runtime model developed for the Space Station environment. The level of support is modular, flexible and dynamically configurable just like the overall runtime support environment. Author

N89-18403*# National Aeronautics and Space Administration, Washington, DC.
DATA SYSTEMS

PAUL H. SMITH *In its* NASA Information Sciences and Human Factors Program p 127-145 Sep. 1988
Avail: NTIS HC A10/MF A01 CSCL 05/2

The Data Systems Program consists of research and technology devoted to controlling, processing, storing, manipulating, and analyzing space-derived data. The objectives are to provide the technology advancements needed to enable affordable utilization of space-derived data, to increase substantially the capability for future missions of on-board processing and recording and to provide high speed and high volume computational systems anticipated for missions such as the evolutionary Space Station and Earth Observing System. The Data Systems Program supports fundamental research in such areas as laser diodes, supports work to select and provide the appropriate on-board processor technology for future NASA missions, and also supports the development of two flight processors with special architectures.
Author

N89-18758# Colorado Univ., Boulder. Lab. for Atmospheric and Space Physics.
INFORMATION SYSTEMS FOR THE SPACE STATION ERA
G. H. LUDWIG *In* ESA, Proceedings of the 1988 International Geoscience and Remote Sensing Symposium (IGARSS) '88 on Remote Sensing: Moving Towards the 21st Century, Volume 3 p 1497-1499 Aug. 1988
Avail: NTIS HC A99/MF A01; ESA Publications Division, ESTEC, Noordwijk, Netherlands, $120 US or 250 Dutch guilders

Space Station research user requirements are discussed. Users will need more discriminating measurements, require higher data rates, and conduct new kinds of interdisciplinary studies. Widely dispersed collaborators will employ data from multiple instruments in studies of global scale, which will necessitate more investigator involvement in planning, control, and use of their data. A user environment must be designed to meet these challenges, and the design concepts should include: a distributed, cohesive system architecture; a homogeneous, stable set of user interfaces; structured systems that can, in many respects, be transparent to users; and easy transfer of data among collaborators. Investigators must take an active role in the development of the systems.
ESA

N89-19336# Iowa Univ., Iowa City. Center for Computer Aided Design.
A RECURSIVE METHOD FOR PARALLEL PROCESSOR MULTIFLEXIBLE BODY DYNAMIC SIMULATION
EDWARD J. HAUG *In* Virginia Univ., Proceedings of the Fifth AFOSR Forum on Space Structures p 13-17 11 Dec. 1987
Avail: NTIS HC A05/MF A01 CSCL 22/5

The purpose of this note is to outline a recently developed method for formulating and solving equations of motion of multibody dynamic systems that is well suited for high speed dynamic simulation using parallel processors. An outline of the approach is given here, with references to papers that develop the mathematical foundations. Examples involving a rigid body vehicle system real-time simulation, a geometrically nonlinear rotating blade, and a space manipulator are used to illustrate application of the method and to indicate computational efficiency that can be gained.
Author

N89-19833*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
VALIDATION OF HIGHLY RELIABLE, REAL-TIME KNOWLEDGE-BASED SYSTEMS
SALLY C. JOHNSON *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 123-129 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 09/2

Knowledge-based systems have the potential to greatly increase the capabilities of future aircraft and spacecraft and to significantly reduce support manpower needed for the space station and other space missions. However, a credible validation methodology must be developed before knowledge-based systems can be used for life- or mission-critical applications. Experience with conventional software has shown that the use of good software engineering techniques and static analysis tools can greatly reduce the time needed for testing and simulation of a system. Since exhaustive testing is infeasible, reliability must be built into the software during the design and implementation phases. Unfortunately, many of the software engineering techniques and tools used for conventional software are of little use in the development of knowledge-based systems. Therefore, research at Langley is focused on developing a set of guidelines, methods, and prototype validation tools for building highly reliable, knowledge-based systems. The use of a comprehensive methodology for building highly reliable, knowledge-based systems should significantly decrease the time needed for testing and simulation. A proven record of delivering reliable systems at the beginning of the highly visible testing and simulation phases is crucial to the acceptance of knowledge-based systems in critical applications.
Author

N89-19838*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
SPACEBORNE VHSIC MULTIPROCESSOR SYSTEM FOR AI APPLICATIONS
HENRY LUM, JR., HOWARD E. SHROBE, and JOHN G. ASPINALL (Symbolics, Inc., Cambridge, MA.) *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 153-160 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 09/2

A multiprocessor system, under design for space-station applications, makes use of the latest generation symbolic processor and packaging technology. The result will be a compact, space-qualified system two to three orders of magnitude more powerful than present-day symbolic processing systems.
Author

N89-19844*# Intellicorp, Mountain View, CA.
BROWSING SCHEMATICS: QUERY-FILTERED GRAPHS WITH CONTEXT NODES
EUGENE C. CICCARELLI and BONNIE A. NARDI *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 193-204 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 09/2

The early results of a research project to create tools for building interfaces to intelligent systems on the NASA Space Station are reported. One such tool is the Schematic Browser which helps users engaged in engineering problem solving find and select schematics from among a large set. Users query for schematics with certain components, and the Schematic Browser presents a graph whose nodes represent the schematics with those components. The query greatly reduces the number of choices presented to the user, filtering the graph to a manageable size. Users can reformulate and refine the query serially until they locate the schematics of interest. To help users maintain orientation as they navigate a large body of data, the graph also includes nodes that are not matches but provide global and local context for the matching nodes. Context nodes include landmarks, ancestors, siblings, children and previous matches.
Author

N89-19867*# Washington Univ., Seattle. Dept. of Electrical Engineering.
CAD-MODEL-BASED VISION FOR SPACE APPLICATIONS
LINDA G. SHAPIRO *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 361-367 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 09/2

A pose acquisition system operating in space must be able to perform well in a variety of different applications including automated guidance and inspections tasks with many different, but known objects. Since the space station is being designed with automation in mind, there will be CAD models of all the objects, including the station itself. The construction of vision models and procedures directly from the CAD models is the goal of this project. The system that is being designed and implementing must convert CAD models to vision models, predict visible features

from a given view point from the vision models, construct view classes representing views of the objects, and use the view class model thus derived to rapidly determine the pose of the object from single images and/or stereo pairs. Author

N89-20084*# Prairie View Agricultural and Mechanical Coll., TX. Dept. of Electrical Engineering.
TIME-DOMAIN IMAGING Final Report
C. L. TOLLIVER *In* NASA, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988, Volume 2 16 p Feb. 1989
Avail: NTIS HC A09/MF A01 CSCL 17/2

The quest for the highest resolution microwave imaging and principle of time-domain imaging has been the primary motivation for recent developments in time-domain techniques. With the present technology, fast time varying signals can now be measured and recorded both in magnitude and in-phase. It has also enhanced our ability to extract relevant details concerning the scattering object. In the past, the interface of object geometry or shape for scattered signals has received substantial attention in radar technology. Various scattering theories were proposed to develop analytical solutions to this problem. Furthermore, the random inversion, frequency swept holography, and the synthetic radar imaging, have two things in common: (1) the physical optic far-field approximation, and (2) the utilization of channels as an extra physical dimension, were also advanced. Despite the inherent vectorial nature of electromagnetic waves, these scalar treatments have brought forth some promising results in practice with notable examples in subsurface and structure sounding. The development of time-domain techniques are studied through the theoretical aspects as well as experimental verification. The use of time-domain imaging for space robotic vision applications has been suggested. Author

N89-25362# Lawrence Livermore National Lab., CA.
TIME DOMAIN MODELING OF ELECTROMAGNETIC COUPLING
R. R. MCLEOD, R. L. BERGER, and L. D. BACON (Sandia National Labs., Albuquerque, NM.) 23 Mar. 1989 10 p Presented at the 4th National Conference on High Power Microwave (HPM) Technology for Defense Applications, Monterey, CA, 9 May 1988 (Contract W-7405-ENG-48)
(DE89-010240; UCRL-97831; CONF-8805132-14) Avail: NTIS HC A02/MF A01

Time-Domain Electromagnetic (EM) codes are increasingly being applied to coupling problems in order to supplement and complement the experimental efforts in this area. Both Finite-Difference Time-Domain (FDTD) and Finite-Element Time-Domain (FETD) techniques are employed to calculate the fields and currents inside of a shielding body. The size of the relevant detail in realistic systems, however, currently limits the usefulness of these codes. This detail problem is investigated, and a number of proposed solutions to it are evaluated. Finally, some example problems, representative of current modeling capabilities, are presented. DOE

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ACCOMMODATIONS

Includes descriptions of simulations, analyses, trade studies, and requirements for safe efficient procedures, facilities, and support equipment on the ground and in space for processing, servicing, maintenance, reliability, commonality, verification and checkout of cargo and equipment.

A89-11812
SENSOR INTEGRATION BY SYSTEM AND OPERATOR
DEWEY RUNDUS (South Florida, University, Tampa, FL) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 64-68. refs

Maintenance of proper functioning of the Space Station will require monitoring of a large number of sensors. This task will include not only state monitoring, but also the need to recognize trends which might lead to fault states. Both types of monitoring would be aided if groups of sensor values could be reduced to a single value which preserved their important characteristics. Multidimensional scaling is proposed as a technique to achieve such a goal. This approach, in addition to being useful in the creation of aids to a human operator, would also have characteristics which would make it a useful sensor integration approach for automated systems. Author

A89-15344* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
AUTOMATED WORKSTATION FOR THE OPERATION OF SPACECRAFT ENGINEERING SUBSYSTEMS
K. A. BAHRAMI, K. L. ATKINS (California Institute of Technology, Jet Propulsion Laboratory, Pasadena), R. SAXON, and N. KAUFMAN (Cypher Master, Inc., Los Angeles, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 367-375.

This paper addresses the development of a workstation that exploits automated tools to enable an operator to monitor concurrently several engineering subsystems and/or several space missions. The use of artificial intelligence and advanced graphics capabilities to achieve fast prototypes is discussed. The monitoring of engineering telemetry data from the Power and Pyro Subsystem of the Galileo spacecraft is emphasized. C.D.

A89-16523#
SPACECRAFT MODULE BERTHING USING TODAY'S TECHNOLOGY
STEWART W. JACKSON, ANTHONY P. MATTHEWS, and OSVALDO L. REGALADO (General Electric Co., Astro-Space Div., Princeton, NJ) AIAA, Space Programs and Technologies Conference, Houston, TX, June 21-24, 1988. 7 p.
(AIAA PAPER 88-3512-A)

An interface device, the intermodule connector (IMC), which will facilitate the on-orbit berthing and assembly of spacecraft modules using the remote manipulator system (RMS), has been developed. An IMC proof-of-concept test was carried out at the Johnson Space Center Manipulator Development Facility to validate the IMC concept and its compatibility with the RMS. The enhanced berthing latch IMC with the Y guide and trunnion alignment system was found to be the most promising near-term configuration for the IMC. K.K.

A89-17103
MAKING ACCELERATION DATA MORE ACCESSIBLE AND USEFUL TO MICROGRAVITY INVESTIGATORS
ANTHONY P. ARROTT (Payload Systems, Inc., Wellesley, MA) Metallurgical Transactions A - Physical Metallurgy and Materials Science (ISSN 0360-2133), vol. 19A, Nov. 1988, p. 2631-2637. refs

Concepts and algorithms for condensing, processing, and presenting portions of acceleration data records are discussed. The on-line data reduction and analysis techniques can reduce the total data storage requirements. By considering the nature of the acceleration measurements in relation to the needs of the microgravity experiments, the present methods can provide more compact and accessible information about the gravitoinertial environment of space experiments. R.R.

A89-17677#
ZERO-GRAVITY MASSMETER FOR ASTRONAUTS AND SPACE STATION EXPERIMENTS
JEROME PEARSON (USAF, Wright Aeronautical Laboratories,

Wright-Patterson AFB, OH) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 6 p.
(IAF PAPER 88-100)

A new device is described for measuring the mass of weightless objects in space vehicles, based on new techniques. The zero-gravity massmeter measures the mass of an unknown object by measuring the change in center of mass between the object and a connected known mass. The new device has advantages over past techniques that depended on the frequency of an unknown mass on a spring. The device can be used over a large range of unknown masses, making it applicable to measuring bone loss in astronauts and the mass of small specimens such as crystal growth experiments. This zero-gravity massmeter technique can also be applied to measure the mass of fuel tanks and other objects tethered to a Space Station, as well as the mass of the station itself. Author

A89-17709*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EARTH TRANSPORTATION NODE REQUIREMENTS AND DESIGN
W. RAY HOOK (NASA, Langley Research Center, Hampton, VA), J. KIRK AYERS, and WILLIAM M. CIRILLO (Planning Research Corp., Hampton, VA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 9 p. refs
(IAF PAPER 88-182)

The objective of this paper is to establish the requirements for an inhabited earth orbiting transportation node and to develop design concepts for such a facility. The use of an earth orbiting transportation node is required to support many of the space flight projects proposed for the beginning of the 21st century. The requirements for such an orbiting facility are derived from the missions which they support. Future missions investigated include automated and human exploration of the solar system, support of a lunar base, and missions to planet earth. Design concepts are presented for transportation nodes based on a variation of the current Space Station Freedom design. Designs accommodate a variety of earth-to-orbit, orbit-to-orbit, and deep-space probe transportation systems. Finally, the technology needed to develop such a transportation node is summarized. Author

A89-18289
AIAA/SOLE SPACE LOGISTICS SYMPOSIUM, 2ND, COSTA MESA, CA, OCT. 3-5, 1988, PROCEEDINGS
Symposium sponsored by the Society of Logistics Engineers and AIAA. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 316 p. For individual items see A89-18290 to A89-18331.

The present conference discusses topics in SDI space logistics concepts and challenges, the influence of logistical considerations on space hardware design, logistical support of ground operations, Space Shuttle logistics concepts, logistical support of orbital systems, and the AI, system-modeling, and computer aids developed for orbital system support. Attention is given to an integrated effectiveness/supportability analysis capability for SDI, new avenues in space logistics, Space Station organization, future civil space systems logistics, the Columbus logistics program, Space Station maintenance concepts, increased autonomy through satellite expert system scheduling, and applications of queuing theory to on-orbit logistics modeling. O.C.

A89-18293#
SOME NECESSARY CONDITIONS FOR SPACE LOGISTICS MODELS
ROBERT L. ABRAMSON, NELSON E. KING, and PHILIP H. YOUNG (Aerospace Corp., El Segundo, CA) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 4 p. USAF-supported research. refs
(AIAA PAPER 88-4708)

A set of requirements to which all logical or mathematical evaluation models for the possible cost savings and operational advantages of a specific spacecraft support infrastructure configuration's implementation should conform is presented. Necessary conditions are formulated for ensuring concept neutrality and model credibility; it is stressed that concept neutrality alone insures proper model output interpretation. Illustrative examples are given, and a categorization is made of the type of model biases encountered. O.C.

A89-18298#
THE IMPACT OF VERY HIGH SPEED INTEGRATED CIRCUIT TECHNOLOGY ON SPACE STATION LOGISTICS
LINCOLN HALLEN (Executive Resource Associates, Inc., Alexandria VA) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 8 p. refs
(AIAA PAPER 88-4714)

The DOD's VHSIC program has generated an electronics technology base that is expected to revolutionize spacecraft on-orbit logistics support processes. It is anticipated that systems will be able to test and recalibrate themselves, as well as repair and reprogram themselves through the active determination of alternative electrical paths. An evaluation is presently made of the maintenance and resupply consequences of these performance capabilities for the NASA Space Station. O.C.

A89-18300#
THE ROLE OF LSAR IN LONG TERM SPACE OPERATIONS AND SPACE MAINTENANCE SUPPORT
STANFORD E. HOFFMAN IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 7 p. refs
(AIAA PAPER 88-4718)

In order to ensure the adequate and timely support required by its Space Station, NASA has undertaken the development, concurrently with Space Station design and development efforts, of the Logistic Support Analysis Record (LSAR) support data-base for planning. MIL-STD-1388-2A is the DOD specification document for SLAR, and will be the point of reference for all contractors involved in the four 'Work Packages' through which the Space Station will be acquired and integrated at the Kennedy Space Center. O.C.

A89-18317*# McDonnell-Douglas Astronautics Co., Houston, TX.
SPACE STATION CORE RESUPPLY AND RETURN REQUIREMENTS ESTIMATION
D. B. WISSINGER (McDonnell Douglas Astronautics Co., Houston, TX) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 11 p.
(Contract NAS9-17885)
(AIAA PAPER 88-4741)

A modular methodology has been developed to model both NASA Space Station onboard resupply/return requirements and Space Shuttle delivery/return capabilities. This approach divides nonpayload Space Station logistics into seven independent categories, each of which is a function of several rates multiplied by user-definable onboard usage scenarios and Shuttle resupply profiles. The categories are summed to arrive at an overall resupply or return requirement. Unused Shuttle resupply and return capacities are also evaluated. The method allows an engineer to evaluate the transportation requirements for a candidate Space Station operational scenario. O.C.

A89-18320#
U.S. SPACE STATION READY SPARES INVENTORY AS DETERMINED FROM PROJECTION OF SPACE SHUTTLE DATA - HOW MUCH IS ENOUGH?
WILLIAM C. LEWIS (Grand Valley State University, Allendale; Research and Technology Institute, Grand Rapids, MI) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute

of Aeronautics and Astronautics, 1988, 10 p. Research supported by the Grand Valley State University and Research and Technology Institute. refs
(AIAA PAPER 88-4744)

A subset of the Shuttle Orbiter maintenance records is used as an analog to the Freedom Station. Estimated ready spares inventory size and terrestrial low-earth-orbit replacement module transport burden are determined for a hypothetical 90-day Shuttle Orbiter mission. These are scaled to describe the Freedom, the U.S. Space Station. Effect of four logistics support policies (unaugmented module replacement, module replacement augmented by repair, augmented by on-demand resupply, and augmented by both) is calculated. Effect of decreased repair time, increased commonality, increased reliability, and all three combined is also calculated for the augmented policy. Comments on calculation of logistics implications of module number reduction and mission length reduction are made. Author

A89-18324#
SPACE STATION MAINTAINABILITY DESIGN REQUIREMENTS FOR LIFE CYCLE COSTS (COMMONALITY AND STANDARDIZATION)
J. A. CRITES and P. G. TREMBLAY (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 4 p.
(AIAA PAPER 88-4749)

The design features required to render the NASA Space Station a highly standardized and high-commonality system in both hardware and software are discussed, giving attention to the maximization of crew safety and minimization of total life cycle cost. It is assumed that the ECLSS is a critical Space Station system; its 15 functions possess an average MTBF of 15,000 hours. High inherent reliability, coupled with a carefully designed capability for controlled cannibalization, will ensure Space Station crew survivability. O.C.

A89-19917*# Calgary Univ. (Alberta).
ROSS-STIRLING SPACECRAFT REFRIGERATOR
G. WALKER (Calgary, University, Canada), M. SCOTT, and S. ZYLSTRA (General Pneumatics Corp., Scottsdale, AZ) (IECEC '87; Proceedings of the Twenty-second Intersociety Energy Conversion Engineering Conference, Philadelphia, PA, Aug. 10-14, 1987. Volume 4, p. 1870-1874) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 25, Sept.-Oct. 1988, p. 341, 342. Abridged. NASA-supported research. Previously cited in issue 02, p. 158, Accession no. A88-11983.

A89-25331*# Grumman Technical Services, Inc., Reston, VA.
A STRATEGY FOR SPACE STATION USER INTEGRATION
PAUL A. LEVITT (Grumman Corp., Grumman Space Station Program Support Div., Reston, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(Contract NASW-4300)
(AIAA PAPER 89-0394)

An approach for the development of a flexible end-to-end user integration process for the Space Station is proposed. Users are assigned to an integration class based on the integration complexity of their payloads. The user, user sponsor, and payload accomodations manager develop an integration timeline for the user. The development of techniques to manage multiple payloads and increments over the life of the Space Station, while minimizing interactions between the integration flows of individual users is considered. The integration classes are defined and the strategic, tactical, and execution planning phases of the process are described. R.B.

A89-26378*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
U.S. LABORATORY MODULE - ITS CAPABILITIES AND ACCOMMODATIONS TO SUPPORT USER PAYLOADS
LUTHER E. POWELL, WALTER V. WOOD, and CHARLES R. BAUGHER, II (NASA, Marshall Space Flight Center, Huntsville, AL) IN: Commercial opportunities in space; Symposium, Taipei, Republic of China, Apr. 19-24, 1987, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 16-33.

The U.S. Laboratory Module of the Space Station is discussed, focusing on user accommodations. The configuration and subsystems capabilities of the module are described, including the power, thermal, environmental control, and data management subsystems, the vacuum system, process materials management, and laboratory support equipment. The experimental facilities included in the laboratory are listed. The experiment operations planned for the laboratory are examined and compared with the experimental activities in other manned space laboratories. R.B.

A89-27805* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
PROCESS MATERIAL MANAGEMENT IN THE SPACE STATION ENVIRONMENT
J. L. PERRY and W. R. HUMPHRIES (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 12 p. refs
(SAE PAPER 880996)

The Space Station will provide a unique facility for conducting material-processing and life-science experiments under microgravity conditions. These conditions place special requirements on the U.S. Laboratory for storing and transporting chemicals and process fluids, reclaiming water from selected experiments, treating and storing experiment wastes, and providing vacuum utilities. To meet these needs and provide a safe laboratory environment, the Process Material Management System (PMMS) is being developed. Preliminary design requirements and concepts related to the PMMS are addressed, and the MSFC PMMS breadboard test facility and a preliminary plan for validating the overall system design are discussed. Author

A89-27844
DIGITAL CONTROL SYSTEM FOR A REFRIGERATOR HEAT PUMP FOR SPACECRAFT ENVIRONMENT
D. PARNITZKI (Swiss Federal Aircraft Factory, Emmen, Switzerland) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 15 p. refs
(SAE PAPER 881044)

This paper describes the development of a microcomputer based control system for a heat pump containing an electrical variable speed compressor drive and a motorized expansion valve. It is designed to operate under very much varying load conditions with minimum power consumption. Difficulties that were encountered during engineering tests could finally be overcome by a relatively simple, practical regulator configuration. It operates near optimum efficiency by regulating a certain temperature difference in the evaporator. Experimental data on operating characteristics and performance are included in the paper. Author

A89-27857* Rockwell International Corp., Downey, CA.
SPACE STATION EVA TEST BED OVERVIEW
RICHARD G. STINSON (Rockwell International Corp., Downey, CA) and MICHAEL E. MONTZ (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 19 p. refs
(SAE PAPER 881060)

Current testing activities, testbed design goals, and future plans to support extravehicular activities (EVAs) of the Space Station are discussed. Developments include: (1) regenerative systems for carbon dioxide provision and removal; (2) increased space suit pressure to minimize prebreathe time; and (3) improved operational efficiencies for the extravehicular mobility units. Much novel technology will undergo integration to constitute the Space Station EVA System. A.A.F.

A89-27911
RESOURCE NODES OUTFITTING
JOHN F. DAILY, FRANK T. EICHSTADT, and JOHN B. LAUGER (McDonnell Douglas Astronautics Co., Space Station Div., Huntington Beach, CA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 13 p.
(SAE PAPER 881120)

This paper discusses designs for outfitting NASA Space Station Resource Nodes. It briefly summarizes the evolution of Resource Nodes to their current configuration and discusses functional and design requirements driving their overall configuration and internal outfitting. Significant features of Resource Node internal architecture, distributed system packaging, crew accommodations, and utility distribution are described. This approach to Resource Node outfitting meets current requirements for crew operations, on-orbit maintainability, and growth for the projected 30-year life of the Space Station. Author

A89-27914* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
OPERATIONAL CONSIDERATIONS FOR THE SPACE STATION LIFE SCIENCE GLOVEBOX
DARYL N. RASMUSSEN (NASA, Ames Research Center, Moffett Field, CA), JOHN J. BOSLEY, KRISTOFER VOGELSONG (NASA, Ames Research Center; Bionetics Corp., Moffett Field, CA), TERY A. SCHNEPP (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA), and ROBERT W. PHILLIPS (Colorado State University, Fort Collins) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 9 p. refs
(SAE PAPER 881123)

The U.S. Laboratory (USL) module on Space Station will house a biological research facility for multidisciplinary research using living plant and animal specimens. Environmentally closed chambers isolate the specimen habitats, but specimens must be removed from these chambers during research procedures as well as while the chambers are being cleaned. An enclosed, sealed Life Science Glovebox (LSG) is the only locale in the USL where specimens can be accessed by crew members. This paper discusses the key science, engineering and operational considerations and constraints involving the LSG, such as bioisolation, accessibility, and functional versatility. Author

A89-27915* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SPACE STATION CUPOLA DEFINITION
LAURIE A. WEAVER (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 12 p. refs
(SAE PAPER 881124)

The concept of a Space Station cupola has evolved from a small bubble-type viewport into the primary location for proximity operations requiring direct unobstructed viewing. Derived from a viewing analysis conducted by the Man-Systems Division at the Johnson Space Center, the cupola represents a solution for out-of-plane viewing which cannot be provided by windows placed in the shell of the habitation and/or laboratory modules. An extended Man-Systems design study resulted in several cupola configurations, each illustrating an alternate solution to the required balance between viewing, projected Space Station operations, and human/machine interface issues. Author

A89-28421*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE MODULAR COMBUSTION FACILITY FOR THE SPACE STATION LABORATORY - A REQUIREMENTS AND CAPABILITIES STUDY
K. R. SACKSTEDER, R. J. CHUCKSA, and R. C. OEFTERING (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 6 p.
(AIAA PAPER 89-0505)

This paper describes a modular combustion facility for the Space Station, designed to provide facility-level services to interchangeable experiment modules, each of which designed specifically for the needs of a particular combustion experiment. The facility-level services are to include computer devices for the data acquisition, experimental control, and data reduction and analysis; the electrical power conversion and control; video cameras and recordings; the cooling-loop supply; waste management; gas supply; precision gas-mixing; and the combustion diagnostics support. Summarized categories of the data base are provided, which were developed to assimilate and to process the responses from the investigators. I.S.

A89-30816*# NASA Space Station Program Office, Reston, VA.
AN ASSESSMENT OF THE STRUCTURAL DYNAMIC EFFECTS ON THE MICROGRAVITY ENVIRONMENT OF A REFERENCE SPACE STATION
STEVE DEL BASSO (Grumman Corp., Space Station Program Support Div., Reston, VA) and ALAN J. LINDENMOYER (NASA, Space Station Freedom Program Office, Reston, VA) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1576-1590. refs
(AIAA PAPER 89-1341)

An interim 'Permanently Manned Capability' Space Station configuration and one designated 'Assembly Complete' are modeled by FEM techniques in order to select forcing functions for modal transient response analysis and illustrate sample waveforms. In all, 114 applied-force cases have been executed to simulate such expected operational disturbances as crewmembers' treadmill exercises and EVAs. The present discussion of the results obtained give attention to the acceleration-response environment of the U.S. Laboratory's center grid-point. The magnitude of the acceleration responses obtained indicate that attenuation systems must be incorporated, or operational constraints must be instituted. O.C.

N89-14254# Sener S.A., Madrid (Spain).
TRANSFER AIRLOCK REQUIREMENTS Final Report
E. ROMERO, C. COMPOSTIZO, J. ESCOBAR, L. SANCHEZ, E. CABRERA, A. I. SKOOG, R. VAETH, and S. LUCK (Dornier-Werke G.m.b.H., Friedrichshafen, Germany, F.R.) Paris, France ESA Jul. 1987 109 p
(Contract ESTEC-7079/87-NL-PH(SC))
(TAL-RP-SN-003; ESA-CR(P)-2637; ETN-89-93167) Avail: NTIS HC A06/MF A01

A study on the airlock for transfer of crewmen from the future European spacecraft Hermes is presented. A comprehensive set of requirements for each airlock subsystem is derived from literature, mainly from American sources. The comparison among different concepts of airlocks leads to the selection of a preferred concept, or baseline airlock. Important functions, such as hyperbaric chamber or safe haven, though possible with the present concept are, on ESA's directive, not included in the baseline configuration. ESA

N89-19442*# California Univ., Irvine.
EXPERIMENT PLANS TO STUDY PREIGNITION PROCESSES OF A POOL FIRE IN LOW GRAVITY M.S. Thesis - 1988 Final Report
DAVID N. SCHILLER Mar. 1989 128 p
(Contract NAG3-627)
(NASA-CR-182256; NAS 1.26:182256) Avail: NTIS HC A07/MF A01 CSCL 22/1

Science requirements are specified to guide experimental studies of transient heat transfer and fluid flow in an enclosure containing a two-layer gas-and-liquid system heated unevenly from above. Specifications are provided for experiments in three separate settings: (1) a normal gravity laboratory, (2) the NASA-LeRC Drop towers, and (3) a space-based laboratory (e.g., Shuttle, Space Station). A rationale is developed for both minimum and desired requirement levels. The principal objective of the experimental effort is to validate a computational model of the enclosed liquid fuel pool during the preignition phase and to

determine via measurement the role of gravity on the behavior of the system. Preliminary results of single-phase normal gravity experiments and simulations are also presented. Author

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GROWTH

Includes descriptions of scenarios, analyses and system technology requirements for the evolutionary growth of the Space Station system.

A89-10487
PLANNING FRAMEWORK FOR HIGH TECHNOLOGY AND SPACE FLIGHT - PROPULSION SYSTEMS [ORIENTIERUNGSRAHMEN HOCHTECHNOLOGIE RAUMFAHRT - ANTRIEBE]
H. KREBS (MBB-ERNO Raumfahrttechnik GmbH, Munich, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 15-22. In German.
(DGLR PAPER 87-073)

Plans for the development of space propulsion systems in the FRG are outlined, with reference to the Planning Framework for High Technology and Space Flight (OHR). The engines considered primary goals in the OHR are 350-400-kN air-breathing or hybrid main engines; high-performance 500-700-kN upper-stage main engines; 20-80-kN chemical or cryogenic engines for OTVs; and small chemical, cryogenic, or electric propulsion systems for AOCS and fine-maneuver applications. The capabilities required of these systems are listed and briefly characterized, and six specific technology-development programs are recommended, focusing on component technology, internal aerodynamics and thermodynamics, new materials and structures, subsystems with variable configurations, engine control and sensor technology, and integrated engine-diagnostics and life-monitoring systems. Also discussed are the new research and test facilities called for by the OHR. T.K.

A89-10488
ENERGY SUPPLY [ENERGIEVERSORGUNG]
J. RATH (AEG AG, Wedel, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 23-31. In German. refs
(DGLR PAPER 87-074)

The recommendations of the Planning Framework for High Technology and Space Flight (OHR) with regard to electric-power systems for future FRG space activities are summarized. It is pointed out that the missions envisioned in the OHR will require significant improvements over present energy systems, including greater production (in excess of 100 kW), greater storage capacity, compatibility with complex onboard equipment and the presence of humans, longer service life, and lower operating costs. Among the systems discussed for use on orbiting platforms are photovoltaic systems; Brayton, Rankine, and Stirling solar-dynamic systems; nuclear systems; and integrated H2/O2 power, life-support, and AOCS propulsion systems. Particular attention is given to the power-supply requirements of space transportation systems. Tables indicating critical technologies and specific OHR recommendations are provided. T.K.

A89-10638* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
NEAR TERM SPACE TRANSPORTATION SYSTEMS FOR EARTH ORBIT AND PLANETARY APPLICATIONS
SIDNEY SAUCIER (NASA, Marshall Space Flight Center, Huntsville, AL) IN: International Pacific Air and Space Technology Conference, Melbourne, Australia, Nov. 13-17, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 149-165. refs
(SAE PAPER 872414)

With the resumption of Space Shuttle flights in mid-1988, many of the initial flights will include a mix of upper stage propulsion systems for geosynchronous orbit and planetary mission applications. This paper presents a system definition and the modifications required to the Inertial Upper Stage and the Transfer Orbit Stage for the near term Space Shuttle missions, namely the Tracking and Data Relay Satellite, Magellan, Galileo, Ulysses, Mars Observer, and the Advanced Communications Technology Satellite. The definition and capabilities of the Orbital Maneuvering Vehicle, currently being developed by NASA to perform a wide range of on-orbit missions and services in support of orbiting spacecraft, are also included. Author

A89-10673* National Aeronautics and Space Administration, Washington, DC.
SPACE STATION UTILIZATION
SHERWIM BECK and RICHARD E. HALPERN (NASA, Office of Space Station, Washington, D.C.) IN: International Pacific Air and Space Technology Conference, Melbourne, Australia, Nov. 13-17, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 519-528.
(SAE PAPER 872462)

This paper focuses on the emphasis NASA has placed on Space Station utilization and the approach used to develop informed user communities in science, technology, and space commercialization. A major program objective continues to be the identification of potential Space Station users, assimilation of user requirements, and the use of those requirements both to drive the Station's design and to guide the Station's evolution. NASA's goal is the creation of a user friendly, multipurpose, multidiscipline research facility that will evolve on-orbit and maintain the position of a premiere space laboratory during its projected 30-year useful life. Author

A89-11354
HIGH-TEMPERATURE SILICON-ON-INSULATOR ELECTRONICS FOR SPACE NUCLEAR POWER SYSTEMS - REQUIREMENTS AND FEASIBILITY
D. M. FLEETWOOD, F. V. THOME, S. S. TSAO, P. V. DRESSENDORFER, V. J. DANDINI (Sandia National Laboratories, Albuquerque, NM) et al. IEEE Transactions on Nuclear Science (ISSN 0018-9499), vol. 35, Oct. 1988, p. 1099-1112. refs
(Contract DE-AC04-76DP-00789)

The authors performed a study to determine whether silicon very large-scale integrated circuits (VLSICs) can survive the high temperature (up to 300 C) and total-dose radiation environments (up to 10 Mrad over a 7-10-y system life) projected for a very-high-power space nuclear reactor platform. It is shown that circuits built on bulk epitaxial silicon cannot meet the temperature requirement because of excessive junction leakage currents. However, circuits built on silicon-on-insulator (SOI) material can meet both the radiation and temperature requirements. It is also found that the temperature dependence of the threshold voltage of the SOI transistors is less than that of bulk transistors. Survivability of high-temperature SOI VLSICs in space, including immunity to transient and single-event upset, is also addressed. I.E.

A89-11810
SYSTEM AUTONOMY HOOKS AND SCARS FOR SPACE STATION
S. A. STARKS and D. W. ELIZANDRO (East Texas State University, Commerce, TX) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 48-52. refs

Some of the more critical hooks and scars which must be inncorporated into the initial operational capability Space Station are addressed. The possible scars required to anticipate implementation of Space Station robots can be characterized into

the following areas: locomotion, vision, and manipulation. In a discussion of software hooks for automation and robotics, particular attention is given to: intelligent system access to sensor, actuator, and control data; allowance for processors with parallel or other advanced architectures; synchronization mechanisms for cooperating intelligent systems; object-oriented design; and the modular approach. K.K.

A89-12305* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PROGRESS TOWARD THE EVOLUTION OF A STIRLING SPACE ENGINE
DONALD L. ALGER (NASA, Lewis Research Center, Cleveland, OH) SAE, International Congress and Exposition, Detroit, MI, Feb. 29-Mar. 4, 1988. 9 p. Previously announced in STAR as N88-14046.
(SAE PAPER 880545)

Following the successful testing of the 25 kWe Space Power Demonstrator (SPD) engine in 1985, a Stirling Space Engine (SSE) technology advancement program was initiated. The program's objective was to advance free-piston Stirling engine/linear alternator technology sufficiently so that a Stirling engine system may become a viable candidate for space power applications. Evolution of the SSE technology is planned to occur at three different engine heater temperature levels: 650, 1050, and 1300 K. These temperatures define three phases of technology development with the first phase involving the 650 K SPD engine. Technology development of the 650 K engine and preliminary design of the 1050 K engine will be discussed. Author

A89-12570
PRELIMINARY DESIGN STUDY OF A 1 MWE SPACE NUCLEAR POWER PLANT
M. MISAWA (Tokyo, University, Japan) and S. KONDO (Tokyo, University, Tokai, Japan) Space Power (ISSN 0951-5089), vol. 7, no. 2, 1988, p. 157-174. refs

The results of a preliminary design study performed on a 1 MWe heat pipe based space nuclear power system capable of being launched in the Space Shuttle are described. Consideration is given to two basic power conversion technologies: thermionic conversion and the Rankine cycle with potassium working fluid. The specific masses for the Rankine and thermionic systems were 9.7 and 5.6 kg/kW, respectively. This preliminary study reveals the feasibility of a 1 MWe nuclear power system for Shuttle launch and suggests that thermionic conversion is preferable to the Rankine cycle. K.K.

A89-12627* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ADVANCED TRANSPORTATION CONCEPT FOR ROUND-TRIP SPACE TRAVEL
CHEN-WAN L. YEN (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 3-16.
(AAS PAPER 87-404)

A departure from the conventional concept of round-trip space travel is introduced. It is shown that a substantial reduction in the initial load required of the Shuttle or other launch vehicle can be achieved by staging the ascent orbit and leaving fuel for the return trip at each stage of the orbit. Examples of round trips from a low-inclination LEO to a high-inclination LEO and from an LEO to a GEO are used to show the merits of the new concept. Potential problem areas and research needed for the development of an efficient space transportation network are discussed. Author

A89-12629
TRANSPORTATION SYSTEM REQUIREMENTS FOR LUNAR MATERIALS DELIVERY TO LEO
STEPHEN HOFFMAN, ALAN FRIEDLANDER, and JOHN NIEHOFF (Science Applications International Corp., Schaumburg, IL) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 33-44. refs
(AAS PAPER 87-406)

The return of lunar material to LEO using lunar-produced liquid oxygen to support space based transportation elements is discussed. A computer-based spreadsheet was used to evaluate parameters affecting system performance, including specific impulse, mixture ratio, structural mass, and aerobraking shield mass. The impact of providing lunar base support from earth is examined and the transportation system is analyzed at three production levels: 100, 500, and 2500 metric tons/yr. It is concluded that additional research is necessary before the performance exceeds the break-even point. R.B.

A89-12654* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
A MARS ROVER MISSION CONCEPT
J. E. RANDOLPH and P. R. TURNER (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 491-509. refs
(AAS PAPER 87-440)

This paper discusses the design concept of the Mars Rover/Sample Return (MRSR) mission. Special consideration is given to the issues of the power source, the scale and performance of the mobility subsystem, the requirements of the sampling subsystem, and the degree of automation, as well as to the features and the orbit design of a Mars orbiting vehicle (MOV) supporting the landed operations. The details of the integrated aeroshell configuration, that includes the rover, the lander, and the MOV during the Mars orbit insertion phase are described, and the diagrams of the MRSR mission and its elements are presented. I.S.

A89-12696* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ADVANCED TECHNOLOGY SPACE STATION STUDIES AT LANGLEY RESEARCH CENTER
MELVIN J. FEREBEE, JR. (NASA, Langley Research Center, Hampton, VA) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 2. San Diego, CA, Univelt, Inc., 1988, p. 1325-1344. refs
(AAS PAPER 87-525)

The paper describes the Advanced Technology Space Station systems studies at Langley Research Center, which were initiated to identify the technologies required for the construction of a high-performance station in the first quarter of the 21st century. Technologies which would maximize the synergistic effects between the subsystems and structural configurations were selected. The ECLSS and propulsion systems show promising synergistic relationships in the areas of oxygen and hydrogen production and attitude control. K.K.

A89-12872
INTERBOARD ENERGY SUPPLY AND TRANSFER
K. B. SERAFIMOV (B'lgarska Akademiia na Naukite, Tsentralna Laboratoriia po Vissha Geodeziia, Sofia, Bulgaria) Bolgarskaia Akademiia Nauk, Doklady (ISSN 0366-8681), vol. 41, no. 8, 1988, p. 61-64.

Transfer of electrical power by SHF transmission between satellites is discussed. It is pointed out that such a technique could decrease satellite mass and complexity and greatly increase satellite useful lifetimes, since battery lifetime would no longer be a limiting factor. Fixed antennas could be used for (1) transfer between GEO satellites (from sunlit satellite to eclipsed satellite), (2) transfer from GEO to satellites at higher orbits, and (3) transfer from solar power satellites to communications or remote-sensing satellites; mobile antennas would be required for transmission to or among LEO satellites. T.K.

A89-14966
ARTIFICIAL GRAVITY NEEDED FOR MISSION TO MARS?
Aerospace Engineering (ISSN 0736-2536), vol. 8, Oct. 1988, p. 10-13.

The possibility of providing artificial gravity for a mission to Mars is discussed. The requirements for constructing a Variable Gravity Research Facility are examined. Various approaches to artificial gravity are considered, including intermittent artificial gravity, spinning the spacecraft about its center, and dividing the spacecraft into separable modules connected by a thin structure which would carry the spin-induced mechanical loads. R.B.

A89-15222
THERMIONIC CONVERSION AND ALLOYS FOR HIGH-TEMPERATURE NUCLEAR SPACE POWER
JAMES F. MORRIS and DEAN L. JACOBSON (Arizona State University, Tempe) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 1. New York, American Society of Mechanical Engineers, 1988, p. 607-611. SDIO-DOE-supported research. refs

Critical future space missions demand near-gigawatt bursts above multimegawatt maintenance levels. These requirements favor space nuclear reactors feeding thermionic energy conversion. With such power systems very high operating temperatures facilitate radiated waste-heat rejection. Operation at thermal maxima also enables utilization of collisionless and oscillating thermionic conversion as well as the conventional arc mode. For all this, advanced-technology ultralloys based on the maximetal tungsten are essential. And in that vein a promising ultralloy approach combines multipurpose modifiers in eutectics that activate tungsten sintering. Resulting ultralloys comprise tungsten and low-concentration dissolved, reacted, precipitated and/or dispersed refractory additives. Appropriate alloy combinations improve not only tungsten performance but also its processing ease, control and effectiveness. Description of these ultralloys and of the improvements they allow in high-temperature thermionic conversion for nuclear space power comprises this presentation. Author

A89-15291
SPACE POWER TECHNOLOGY FOR THE 21ST CENTURY (SPT21)
WILLIAM U. BORGER and LOWELL D. MASSIE (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 1-7. refs

A brief overview is given of planning studies for military space power technology development, undertaken under USAF sponsorship during 1987. Consideration is given to the planning process itself, the planning drivers, and the primary options identified, which include hardened solar photovoltaic systems, hardened compact space nuclear reactors, hardened solar thermal-dynamic systems, and very lightweight minimally hard solar or nuclear systems. Also discussed are critical electrical and thermal support technologies and advanced concepts. The major aspects addressed are listed in extensive charts and graphs. T.K.

A89-15311
DYNAMIC ISOTOPE POWER SYSTEM COMPONENT DEMONSTRATIONS
RICHARD J. PEARSON (Grumman Corp., Space System Div., Bethpage, NY) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 137-143.
(Contract F04701-85-C-0090)

Results are reported from tests on critical components of the closed-Brayton-cycle and organic-Rankine-cycle power-conversion systems being developed for the DOE/DOD Dynamic Isotope Power System (DIPS) program for future military and civilian space missions. Particular attention is given to the test procedures for management of two-phase flow in the Rankine system (test-fluid selection, shear-controlled condenser, and rotary fluid-management device) and the rig and procedure for endurance testing of foil gas bearings for the Brayton system. Diagrams, drawings, graphs, photographs, and tables of numerical data are provided. T.K.

A89-15330
GROUND TESTING OF AN SP-100 PROTOTYPIC REACTOR
K. MOTWANI, G. R. PFLASTERER, H. UPTON, J. D. LAZARUS, and R. GLUCK (General Electric Co., Astro-Space Div., San Jose, CA) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 275-279.

The SP-100 space power system's prototype reactor will be tested to demonstrate the performance of the integrated nuclear reactor, flight shield, and control system; the test methodology will simulate flight operating conditions while meeting all necessary nuclear safety requirements in a gravity environment. The confidence thus established in the design maturity of the SP-100 will expedite flight mission design efforts. O.C.

A89-15392* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EXTENDED SP-100 REACTOR POWER SYSTEMS CAPABILITY
H. S. BLOOMFIELD, J. M. WINTER, B. I. MCKISSOCK, and R. J. SOVIE (NASA, Lewis Research Center, Cleveland, OH) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 671, 672.

The SP-100 space nuclear power system development program and the NASA Civil Space Technology Initiative (CSTI) are discussed. The advanced technologies being developed for the CSTI high capacity nuclear reactor power system are outlined. The relationship between the CSTI and the Pathfinder project is considered. R.B.

A89-16195* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
A TRANSPORTATION SYSTEM FOR ROUTINE VISITS TO MARS
BARNEY B. ROBERTS (NASA, Johnson Space Center, Houston, TX) IN: The NASA Mars Conference. San Diego, CA, Univelt, Inc., 1988, p. 433-453.
(AAS PAPER 86-174)

A conceptual transportation system designed for routing visits to Mars is described. The system is planned to provide routine support for a base population of roughly 20 people on Mars. The system utilizes in situ resource production to support Mars missions and generates artificial gravity while delivering additional consumables. The system uses cycling space stations for support. Possible lunar resource capabilities, taxi vehicles, and technology and human issues are examined. R.B.

A89-16506*# McDonnell-Douglas Astronautics Co., Huntington Beach, CA.
ADAPTION OF SPACE STATION TECHNOLOGY FOR LUNAR OPERATIONS
J. M. GARVEY (McDonnell Douglas Astronautics Co., Space Station Div., Huntington Beach, CA) Lunar and Planetary Institute, Symposium on Lunar Bases and Space Activities of the 21st Century, Houston, TX, Apr. 5-7, 1988, Paper. 20 p. refs
(Contract NAS9-17367)

The possible use of Space Station technology in a lunar base program is discussed, focusing on the lunar lander/ascent vehicles and surface modules. The application of the Space Station data management system, software, and communications, tracking, guidance, navigation, control, and power technologies is examined. The benefits of utilizing this technology for lunar operations are considered. R.B.

A89-17711#
SPACE TRANSFER SYSTEM EVOLUTION TO SUPPORT LUNAR AND MARS MISSIONS
MARK WILLIAM HENLEY (General Dynamics Corp., Space Systems Div., San Diego, CA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 9 p. refs
(IAF PAPER 88-184)

Space transfer vehicles and supporting orbital facilities, to be developed for initial application in earth orbit, can be adaptable for use in manned exploration of the moon and Mars. An initial system with modular construction will allow easy modification to meet additional requirements of future missions. System modifications for early missions to the moon and Mars include man-rating, increased mission duration and velocity, and vehicle derivatives for landing. Continuing system evolution may involve adaptation for new propulsion systems and use of extraterrestrial resources. Near-term development of an initial system is necessary to allow time for the system to mature for manned exploration of the moon and Mars early in the next century. Author

A89-17726#
ORBITAL CRYOGENIC DEPOT FOR SUPPORT OF SPACE TRANSFER VEHICLE OPERATIONS
JOHN R. SCHUSTER (General Dynamics Corp., Space Systems Div., San Diego, CA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 7 p. refs
(IAF PAPER 88-205)

An ongoing study has examined the requirements for a low-earth-orbit (LEO) cryogenic propellant storage depot to support projected future space transportation missions. A reusable space transportation vehicle (STV) based in LEO will require a depot with a 90,000-kg storage capacity for LO2/LH2, which can best be met with two tank sets of 45,000 kg capacity. The tank sets employ many advanced features to provide for microgravity fluid management and to limit cryogen boiloff. Basing the depot on a coorbiting platform is attractive compared with basing it at the manned Space Station due to concerns over Space Station crew safety, contamination, and microgravity environment. A platform should permit venting of boiloff, while basing on the Space Station may require the use of active cryogenic refrigeration to reliquefy boiloff. Depot on-orbit buildup and maintenance estimates are modest, but there could be a substantial need for robotics. An earth-to-orbit propellant resupply tanker capacity of 73,000 kg provides the best match for the depot, thus defining a mission for a future heavy-lift launch vehicle. Author

A89-17730*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PHOTOVOLTAICS FOR HIGH CAPACITY SPACE POWER SYSTEMS
DENNIS J. FLOOD (NASA, Lewis Research Center, Cleveland, OH) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p. Previously announced in STAR as N89-10122. refs
(IAF PAPER 88-221)

The anticipated energy requirements of future space missions will grow by factors approaching 100 or more, particularly as a permanent manned presence is established in space. The advances that can be expected in solar array performance and lifetime, when coupled with advanced, high energy density storage batteries and/or fuel cells, will continue to make photovoltaic energy conversion a viable power generating option for the large systems of the future. The specific technologies required to satisfy any particular set of power requirements will vary from mission to mission. Nonetheless, in almost all cases the technology push will be toward lighter weight and higher efficiency, whether of solar arrays of storage devices. This paper will describe the content and direction of the current NASA program in space photovoltaic technology. The paper will also discuss projected system level capabilities of photovoltaic power systems in the context of some of the new mission opportunities under study by NASA, such as a manned lunar base, and a manned visit to Mars. Author

A89-17845*# NASA Space Station Program Office, Reston, VA.
A SPACE STATION CREW RESCUE AND EQUIPMENT RETRIEVAL SYSTEM
RUDOLPH J. ADORNATO and RONALD A. BO (NASA, Space Station Freedom Program Office, Reston, VA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 7 p.
(IAF PAPER 88-516)

This paper studies the possible use of a Space Station crew rescue and equipment retrieval system as a safeguard against the inadvertent separation of crew or equipment from the Space Station. The time to effect rescue and retrieval and the problem of crew separation are discussed. Alternate rescue/retrieval systems are evaluated. It is concluded that telerobotic vehicles provide the lowest cost rescue capability. R.B.

A89-17861*# General Dynamics Corp., San Diego, CA.
AN ANALYSIS OF POSSIBLE ADVANCED SPACE STRATEGIES FEATURING THE ROLE OF SPACE RESOURCE UTILIZATION
BRUCE CORDELL and OTTO STEINBRONN (General Dynamics Corp., Space Systems Div., San Diego, CA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p. refs
(Contract NAS3-24564)
(IAF PAPER 88-587)

Unresolved issues in space planning in the U.S. are examined, focusing on space resource utilization. The role of the Space Station, determining the most profitable space exploration strategies, and space resource use are discussed. Performance modeling suggests that lunar oxygen is useful on the moon and economical in LEO if lunar hydrogen is available. It is found that the use of volatile materials from Phobos and Deimos might be undertaken if lunar hydrogen is unavailable. It is suggested that resource synergisms between operations in the Mars system and in earth-moon space have important commercial possibilities. R.B.

A89-17877#
MALEO - STRATEGY FOR LUNAR BASE BUILD-UP
M. THANGAVELU and G. E. DORRINGTON (MIT, Boston, MA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 8 p. refs
(IAF PAPER ST-88-15)

Module Assembly at Low Earth Orbit (MALEO) is a strategy for building a lunar base. An assembly of four modules are integrated near the Space Station 'Freedom', tested and shipped to low lunar orbit by a large orbital transfer vehicle. A lander stage is sent to dock with the MALEO and the entire spacecraft/base descended to the lunar surface. A superstructure is an integral part of the MALEO strategy and helps to uniformly distribute loads encountered during the touchdown. The base is operational shortly after landing with minimum EVA operations which is considered as undesirable on the lunar surface. Some major advantages of the MALEO strategy are pointed out. Author

A89-18325*# Martin Marietta Corp., Denver, CO.
MIXED FLEET ASSESSMENT FOR ON-ORBIT CONSUMABLES RESUPPLY
RALPH N. EBERHARDT and SAM M. DOMINICK (Martin Marietta Corp., Denver, CO) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 9 p. Research supported by Martin Marietta Internal Research and Development Funds. refs
(Contract NAS9-17585; NAS9-17854)
(AIAA PAPER 88-4750)

Significant increases in the cost effectiveness and operational flexibility of in-space systems can be realized when the capability to replenish consumable fluids and propellants is incorporated into the designs of spacecraft, satellites, and orbiting platforms and laboratories. Reusable tankers are currently being designed for

transporting fluids to space. A number of options exist for transporting the fluids and propellants tc the space-based user systems. The fluids can be transported to space either in the Shuttle cargo bay or using Expendable Launch Vehicles (ELVs). Resupply can thus be accomplished either from the Shuttle bay, or the tanker can be removed from an ELV and attached to a carrier such as the Orbital Maneuvering Vehicle (OMV) or Orbital Transfer Vehicle (OTV) for transport to the user to be serviced. A third option involves locating the tanker at the Space Station or an unmanned platform as a quasi-permanent servicing facility which returns to the ground for recycling once its tanks have been depleted. This paper documents the impacts of a mixed fleet approach to consumables logistics to orbit. Both storable fluids and propellants, and superfluid helium, are considered. Current modular tanker designs for monopropellants, bipropellants and water for Space Station propulsion are discussed. Trade-offs in superfluid helium tanker sizes, shapes to fit the range of ELVs currently available, and boil-off losses associated with longer-term (greater than 6 months) space-basing, are addressed. Author

A89-19922#
MODULAR, ION-PROPELLED, ORBIT-TRANSFER VEHICLE
J. HERMEL, R. A. MEESE, W. P. ROGERS, R. O. KUSHIDA (Hughes Aircraft Co., Los Angeles, CA), J. R. BEATTIE (Hughes Research Laboratories, Malibu, CA) et al. Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 25, Sept.-Oct. 1988, p. 368-374. Previously cited in issue 07, p. 864, Accession no. A87-21502. refs

A89-19923*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
NUCLEAR-ELECTRIC REUSABLE ORBITAL TRANSFER VEHICLE
LEONARD D. JAFFE (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 25, Sept.-Oct. 1988, p. 375-381. DOD-DOE-sponsored research. refs

To help determine the systems requirements for a 300-kWe space nuclear reactor power system, a mission and spacecraft have been examined that utilize electric propulsion supported by the nuclear reactor's power for multiple transfers of cargo between low earth orbit (LEO) and geosynchronous earth orbit (GEO). A propulsion system employing ion thrusters and xenon propellant was selected. Propellant and thrusters are replaced after each sortie to GEO. The mass of the orbital transfer vehicle (OTV), empty and dry, is 11,000 kg; nominal propellant load is 5000 kg. The OTV operates between a circular orbit at 925-km altitude, 28.5-deg inclination, and GEO. Cargo is brought to the OTV by Shuttle and an orbital maneuvering vehicle (OMV); the OTV then takes it to GEO. The OTV can also bring cargo back from GEO for transfer by OMV to the Shuttle. OTV propellant is resupplied, and the ion thrusters are replaced, by the OMV before each sortie to GEO. At the end of mission life, the OTV's electric propulsion is used to place it in a heliocentric orbit so that the reactor will not return to earth. The nominal cargo capability to GEO is 6000 kg, with a transit time of 120 days; 1350 kg can be transferred in 90 days, and 14,300 kg in 240 days. These capabilities can be considerably increased by using separate Shuttle launches to bring up propellant and cargo or by changing to mercury propellant. Author

A89-20016* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A NEW SPACE STATION POWER SYSTEM
GEOFFREY A. LANDIS (NASA, Lewis Research Center, Cleveland, OH; Brown University, Providence, RI) Acta Astronautica (ISSN 0094-5765), vol. 17, Sept. 1988, p. 975-977. refs

A new concept for a Space Station power system is proposed which reduces the drag effect of the solar panels and eliminates eclipsing by the Earth. The solar generator is physically separated from the Space Station, and power transmitted to the station by a microwave beam. The power station can thus be placed high enough that drag is not a significant factor. For a resonant orbit where the ratio of periods s:p is a ratio of odd integers, and the orbital planes nearly perpendicular, an orbit can be chosen such that the line of sight is never blocked if the lower orbit has an altitude greater than calculatable mininum. For the 1:3 resonance, this minimum altitude is 0.5 r(e). Finally, by placing the power station into a sun-synchronous orbit, it can be made to avoid shadowing by the Earth, thus providing continuous power. Author

A89-25290*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PLANETARY MISSION DEPARTURES FROM SPACE STATION ORBIT
ANDREY B. SERGEYEVSKY (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs
(AIAA PAPER 89-0345)

The concept of orbital assembly and launch of oversized planetary (or lunar) spacecraft from a Space Station is rapidly coming of age. This prospect raises a host of new problems demanding timely resolution. The one most serious issue involved in launch from a rapidly precessing Space Station orbit (about -7.2 deg/day) is the need to cope with the generally out-of-plane orientation of the V-infinity departure vector. Methods dealing with single or multiple injection maneuvers, deep space plane changes, nodal shift caused by reboost strategy modifications, and departure window duration analysis are discussed. Author

A89-25332#
GARAGE IN THE SKY - A SERVICE CENTER FOR SPACE STATION
CHRISTOPHER J. SPITZER (Booz, Allen and Hamilton, Inc., Arlington, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(AIAA PAPER 89-0397)

A service center is being developed for equipment replacement, refueling, general maintenance, and cryogenic resupply on the Space Station. The advantages of on-orbit spacecraft servicing and the servicing center requirements are reviewed. The service center configuration and equipment are described and illustrated. The possible use of the center and its orbit maneuvering vehicle to service the Hubble Space Telescope, the process for delivering the center to the Space Station on the Space Shuttle, and the possible growth of the service center into an independent spaceport facility are discussed. R.B.

A89-25503*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ASCENT, ABORT, AND ENTRY CAPABILITY ASSESSMENT OF A SPACE STATION RESCUE AND PERSONNEL/LOGISTICS VEHICLE
J. C. NAFTEL, R. W. POWELL, and T. A. TALAY (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p.
(AIAA PAPER 89-0635)

The ascent, abort, and entry capability of a vehicle for rescue of the Space Station crew or ferry of personnel and supplies to and from the Space Station are analyzed. The configurations of the Space Station rescue vehicle and the Space Station personnel/logistics vehicle (SSPLV) are discussed and illustrated. The nominal ascent trajectory for the SSPLV delivered to orbit on a Titan II is presented. The ascent abort modes from launch to orbital injection are evaluated. It is shown that five landing sites with runways longer than 10,000 ft could provide a landing opportunity from every orbit of the Space Station in a 220-nmi circular orbit with a 28.5 deg inclination. R.B.

A89-26403#
LIGHT WEIGHT ELECTROSTATIC GENERATOR FOR AEROSPACE AND OTHER USES - CYLINDRICAL PARAMETRIC GENERATOR
F. CAP (Innsbruck, Universitaet, Austria) IN: Commercial

opportunities in space; Symposium, Taipei, Republic of China, Apr. 19-24, 1987, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 475-488. refs

Using a time-varying capacity, a principle to convert mechanic energy into electric energy is described. Arbitrary and sinusoidal time varying high-voltages can be produced. The generator consists of rotating slotted hollow cylinders. On the basis of the solution of the boundary problem of these cylinders, the parametric pump function of the device is derived. Using a nonlinear mechanism, stability of the device is guaranteed. Author

A89-29116*# Garrett Corp., Torrance, CA.
ADVANCED SOLAR RECEIVERS FOR SPACE POWER
H. J. STRUMPF, M. G. COOMBS (Garrett Corp., Garrett AiResearch Div., Torrance, CA), and D. E. LACY (NASA, Lewis Research Center, Cleveland, OH) IN: Solar engineering - 1988; Proceedings of the Tenth Annual ASME Solar Energy Conference, Denver, CO, Apr. 10-14, 1988. New York, American Society of Mechanical Engineers, 1988, p. 343-352.

A study has been conducted to generate and evaluate advanced solar heat receiver concepts suitable for orbital application with Brayton and Stirling engine cycles in the 7-kW size range. The generated receiver designs have thermal storage capability and, when implemented, will be lighter, smaller, and/or more efficient than baseline systems such as the configuration used for the Brayton solar receiver under development by Garrett AiResearch for the NASA Space Station. In addition to the baseline designs, four other receiver concepts were designed and evaluated with respect to Brayton and Stirling engines. These concepts include a higher temperature version of the baseline receiver, a packed bed receiver, a plate-fin receiver, and a heat pipe receiver. The thermal storage for all designs is provided by the melting and freezing of a salt. Author

A89-29407
THE RE-ENTRY ENVIRONMENT OF THE MULTI-ROLE CAPSULE
I. WALTERS and C. M. HEMPSELL (British Aerospace, PLC, Space and Communications Div., Stevenage, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 42, Feb. 1989, p. 88-91.

This paper describes the structural loading and the thermodynamic environment experienced by the baseline Multi-Role Capsule during reentry from orbit and for a proposed asymmetric alternative configuration. The baseline Multi-Role Capsule follows the same reentry philosophy as the American Gemini and Apollo capsules. To explore the possibility of a more benign reentry, an alternative capsule shape was analyzed, which can be trimmed to fly at higher angles of incidence giving a higher L/D ratio. This was achieved by a asymmetric conical body which produces an offset C(g) and at the same time allow higher angles of incidence. The alternative shape can fly at 39 deg incidence giving a lift-to-drag ratio of 0.55. This lowers the peak g levels experienced to 1.6 and significantly improves the achievable cross range. Author

A89-31748
STATUS OF THE RITA - EXPERIMENT ON EURECA
H. BASSNER, H.-P. BERG, W. BIRNER (Messerschmitt-Boelkow-Blohm GmbH, Ottobrunn, Federal Republic of Germany), C. BARTOLI, and A. TRIPPI (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 42, March 1989, p. 121-126.

The development of the Radio-frequency Ion Thruster Assembly for the European Retrievable Carrier, Eureca I, is discussed. The Eureca I spacecraft and mission configurations are reviewed. The Eureca spacecraft is expected to be launched and recovered by the Space Shuttle in the early 1990s. The RITA-10 operation and design are described, including the use of Xenon gas as the propellant, and the automatic operation of the experiment with an onboard microcomputer system. The mission is planned to verify the use of the RITA electric propulsion system in space. R.B.

N89-11780*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
GROWTH REQUIREMENTS FOR MULTIDISCIPLINE RESEARCH AND DEVELOPMENT ON THE EVOLUTIONARY SPACE STATION
BARRY MEREDITH, PETER AHLF, RUDY SAUCILLO, and DAVID EAKMAN (McDonnell-Douglas Astronautics Co., Rockville, Md.) Sep. 1988 146 p
(NASA-TM-101497; NAS 1.15:101497) Avail: NTIS HC A07/MF A01 CSCL 22/1

The NASA Space Station Freedom is being designed to facilitate on-orbit evolution and growth to accommodate changing user needs and future options for U.S. space exploration. In support of the Space Station Freedom Program Preliminary Requirements Review, The Langley Space Station Office has identified a set of resource requirements for Station growth which is deemed adequate for the various evolution options. As part of that effort, analysis was performed to scope requirements for Space Station as an expanding, multidiscipline facility for scientific research, technology development and commercial production. This report describes the assumptions, approach and results of the study. Author

N89-11807*# Arizona State Univ., Tempe. Dept. of Electronics and Computer Technology.
IDENTIFICATION OF HIGH PERFORMANCE AND COMPONENT TECHNOLOGY FOR SPACE ELECTRICAL POWER SYSTEMS FOR USE BEYOND THE YEAR 2000 Final Technical Report, 16 May 1986 - 15 Dec. 1988
JAMES E. MAISEL 5 Dec. 1988 227 p
(Contract NAG3-714)
(NASA-CR-183003; NAS 1.26:183003) Avail: NTIS HC A11/MF A01 CSCL 10/2

Addressed are some of the space electrical power system technologies that should be developed for the U.S. space program to remain competitive in the 21st century. A brief historical overview of some U.S. manned/unmanned spacecraft power systems is discussed to establish the fact that electrical systems are and will continue to become more sophisticated as the power levels appoach those on the ground. Adaptive/Expert power systems that can function in an extraterrestrial environment will be required to take an appropriate action during electrical faults so that the impact is minimal. Manhours can be reduced significantly by relinquishing tedious routine system component maintenance to the adaptive/expert system. By cataloging component signatures over time this system can set a flag for a premature component failure and thus possibly avoid a major fault. High frequency operation is important if the electrical power system mass is to be cut significantly. High power semiconductor or vacuum switching components will be required to meet future power demands. System mass tradeoffs have been investigated in terms of operating at high temperature, efficiency, voltage regulation, and system reliability. High temperature semiconductors will be required. Silicon carbide materials will operate at a temperature around 1000 K and the diamond material up to 1300 K. The driver for elevated temperature operation is that radiator mass is reduced significantly because of inverse temperature to the fourth power. Author

N89-11809*# Wisconsin Univ., Madison.
STUDY OF THE GENERATOR/MOTOR OPERATION OF INDUCTION MACHINES IN A HIGH FREQUENCY LINK SPACE POWER SYSTEM Final Report
THOMAS A. LIPO and PRADEEP K. SOOD Mar. 1987 185 p
(Contract NAG3-631)
(NASA-CR-179600; NAS 1.26:179600) Avail: NTIS HC A09/MF A01 CSCL 10/2

Static power conversion systems have traditionally utilized dc current or voltage source links for converting power from one ac or dc form to another since it readily achieves the temporary energy storage required to decouple the input from the output. Such links, however, result in bulky dc capacitors and/or inductors and lead to relatively high losses in the converters due to stresses on the semiconductor switches. The feasibility of utilizing a high frequency sinusoidal voltage link to accomplish the energy storage

and decoupling function is examined. In particular, a type of resonant six pulse bridge interface converter is proposed which utilizes zero voltage switching principles to minimize switching losses and uses an easy to implement technique for pulse density modulation to control the amplitude, frequency, and the waveshape of the synthesized low frequency voltage or current. Adaptation of the proposed topology for power conversion to single-phase ac and dc voltage or current outputs is shown to be straight forward. The feasibility of the proposed power circuit and control technique for both active and passive loads are verified by means of simulation and experiment. Author

N89-13482*# Bionetics Corp., Hampton, VA.
SYSTEM DESIGN ANALYSES OF A ROTATING ADVANCED-TECHNOLOGY SPACE STATION FOR THE YEAR 2025 Interim Report, Nov. 1987 - May 1988
M. J. QUEIJO, A. J. BUTTERFIELD, W. F. CUDDIHY, R. W. STONE, J. R. WROBEL, P. A. GARN, and C. B. KING Dec. 1988 250 p
(Contract NAS1-18267)
(NASA-CR-181668; NAS 1.26:181668) Avail: NTIS HC A11/MF A01 CSCL 22/2

Studies of an advanced technology space station configured to implement subsystem technologies projected for availability in the time period 2000 to 2025 is documented. These studies have examined the practical synergies in operational performance available through subsystem technology selection and identified the needs for technology development. Further analyses are performed on power system alternates, momentum management and stabilization, electrothermal propulsion, composite materials and structures, launch vehicle alternates, and lunar and planetary missions. Concluding remarks are made regarding the advanced technology space station concept, its intersubsystem synergies, and its system operational subsystem advanced technology development needs. Author

N89-13492*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
POWER CONSIDERATIONS FOR AN EARLY MANNED MARS MISSION UTILIZING THE SPACE STATION
MARTIN E. VALGORA 1987 15 p Presented at Case for Mars 3, Boulder, Colo., 18-22 Jul. 1987; sponsored by American Aeronautical Society, JPL, Los Alamos National Lab., Ames Research Center, Lyndon B. Johnson Space Center, George C. Marshall Space Flight Center, Planetary Society
(NASA-TM-101436; E-4472; NAS 1.15:101436) Avail: NTIS HC A03/MF A01 CSCL 10/2

Power requirements and candidate electrical power sources were examined for the supporting space infrastructure for an early (2004) manned Mars mission. This two-year mission (60-day stay time) assumed a single six crew piloted vehicle with a Mars lander for four of the crew. The transportation vehicle was assumed to be a hydrogen/oxygen propulsion design with or without large aerobrakes and assembled and checked out on the LEO Space Station. The long transit time necessitated artificial gravity of the crew by rotating the crew compartments. This rotation complicates power source selection. Candidate power sources were examined for the Lander, Mars Orbiter, supporting Space Station, co-orbiting Propellant Storage Depot, and alternatively, a co-orbiting Propellant Generation (water electrolysis) Depot. Candidates considered were photovoltaics with regenerative fuel cells or batteries, solar dynamics, isotope dynamics, and nuclear power. Author

N89-14251*# Boeing Aerospace Co., Huntsville, AL.
SPACE STATION COMMONALITY ANALYSIS
1988 205 p
(Contract NAS8-36413)
(NASA-CR-179422; NAS 1.26:179422) Avail: NTIS HC A10/MF A01 CSCL 22/2

This study was conducted on the basis of a modification to Contract NAS8-36413, Space Station Commonality Analysis, which was initiated in December, 1987 and completed in July, 1988. The objective was to investigate the commonality aspects of subsystems and mission support hardware while technology experiments are accommodated on board the Space Station in the mid-to-late 1990s. Two types of mission are considered: (1) Advanced solar arrays and their storage; and (2) Satellite servicing. The point of departure for definition of the technology development missions was a set of missions described in the Space Station Mission Requirements Data Base. (MRDB): TDMX 2151 Solar Array/Energy Storage Technology; TDMX 2561 Satellite Servicing and Refurbishment; TDMX 2562 Satellite Maintenance and Repair; TDMX 2563 Materials Resupply (to a free-flyer materials processing platform); TDMX 2564 Coatings Maintenance Technology; and TDMX 2565 Thermal Interface Technology. Issues to be addressed according to the Statement of Work included modularity of programs, data base analysis interactions, user interfaces, and commonality. The study was to consider State-of-the-art advances through the 1990s and to select an appropriate scale for the technology experiments, considering hardware commonality, user interfaces, and mission support requirements. The study was to develop evolutionary plans for the technology advancement missions. Author

N89-15043*# Arizona Univ., Tucson. Dept. of Planetary Sciences, Lunar and Planetary Lab.
EXPERIMENTAL CONSTRAINTS ON THE ORIGIN OF CHONDRULES Abstract Only
W. V. BOYNTON, DRAKE, HILDEBRAND, JONES, LEWIS, TREIMAN, and WARK *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 2 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 03/2

Chrondule formation was an important (perhaps ubiguitous) process in the early solar system, yet their origins remain elusive. Some points, however, are clear. The precursor material of chondules (dust) was rapidly heated at rates of perhaps thousands of degrees per second and was cooled more slowly. It was proposed to investigate chondrule formation in the Space Station environment via a dust-box (a chamber in which dust can be suspended, heated, and cooled. A microgravity environment is conducive to this kind of experiment because of the significant retardation of settling rates compared with a terrestrial laboratory environment. These long-duration experiments might require the development of technologies to counteract even the small, but finite and permanent gravitation field of the Space Station. Simple, but interesting experiments on dust suspensions immediately present themselves. Author

N89-15149*# Battelle Columbus Labs., OH.
SPACE STATION LONG-TERM LUBRICATION ANALYSIS Monthly Progress Report, 1-30 Sep. 1985
K. F. DUFRANE and E. E. MONTGOMERY 15 Oct. 1985 7 p Prepared in cooperation with Spectra Research Systems, Inc., Huntsville, AL
(Contract NAS8-36655)
(NASA-CR-178882; NAS 1.26:178882) Avail: NTIS HC A02/MF A01 CSCL 22/2

The objectives of this program are: (1) to perform a complete tribology survey of every point of contact in the space station subject to relative motion regarding the materials, environment, and operation characteristics, (2) to review each point of relative motion regarding the selected materials and lubricants from the standpoint of the required operating characteristics and environmental conditions, (3) to make recommendations for improvements where the lubricants and/or materials are not considered optimum, and (4) to perform or recommend simulated or full-scale tests on components where problems are possible or likely because of new designs, significant design extensions beyond current practice, or sensitivity of other components to problems with a particular point of contact. The project is to be conducted over a 3-year time frame in two phases. Phase 1 will be a preliminary analysis conducted during the preliminary design phases of the Space Station. Phase 2 will be a more detailed analysis conducted during the period when the design becomes more established. Author

N89-15933*# Houston Univ., TX. Coll. of Architecture.
ANTARCTIC PLANETARY TESTBED (APT): A FACILITY IN THE ANTARCTIC FOR RESEARCH, PLANNING AND SIMULATION OF MANNED PLANETARY MISSIONS AND TO PROVIDE A TESTBED FOR TECHNOLOGICAL DEVELOPMENT
MASHID AHMADI, ALEJANDRO HORACIO BOTTELLI, FERNANDO LUIS BRAVE, and MUHAMMAD ALI SIDDIQUI 16 May 1988 41 p
(Contract NGT-21-002-080)
(NASA-CR-184735; NAS 1.26:184735) Avail: NTIS HC A03/MF A01 CSCL 14/2

The notion of using Antarctica as a planetary analog is not new. Ever since the manned space program gained serious respect in the 1950's, futurists have envisioned manned exploration and ultimate colonization of the moon and other extraterrestrial bodies. In recent years, much attention has been focused on a permanently manned U.S. space station, a manned Lunar outpost and a manned mission to Mars and its vicinity. When such lofty goals are set, it is only prudent to research, plan and rehearse as many aspects of such a mission as possible. The concept of the Antarctic Planetary Testbed (APT) project is intended to be a facility that will provide a location to train and observe potential mission crews under conditions of isolation and severity, attempting to simulate an extraterrestrial environment. Antarctica has been considered as an analog by NASA for Lunar missions and has also been considered by many experts to be an excellent Mars analog. Antarctica contains areas where the environment and terrain are more similar to regions on the Moon and Mars than any other place on Earth. These features offer opportunities for simulations to determine performance capabilities of people and machines in harsh, isolated environments. The initial APT facility, conceived to be operational by the year 1991, will be constructed during the summer months by a crew of approximately twelve. Between six and eight of these people will remain through the winter. As in space, structures and equipment systems will be modular to facilitate efficient transport to the site, assembly, and evolutionary expansion. State of the art waste recovery/recycling systems are also emphasized due to their importance in space. Author

N89-15968*# Texas Univ., Austin. The Mars Company.
DESIGN OF A FAST CREW TRANSFER VEHICLE TO MARS Final Report
6 May 1988 127 p Prepared in cooperation with Universities Space Research Association, Houston, TX
(Contract NGT-21-002-080)
(NASA-CR-184713; NAS 1.26:184713; RFP-ASE274L) Avail: NTIS HC A07/MF A01 CSCL 22/2

A final report is made on the trajectory and vehicle requirements for a fast crew transfer vehicle to Mars which will complete an Earth to Mars (and Mars to Earth) transfer in 150 days and will have a stay time at Mars of 40 days. This vehicle will maximize the crew's effectiveness on Mars by minimizing detrimental physiological effects such as bone demineralization and loss of muscle tone caused by long period exposure to zero gravity and radiation from cosmic rays and solar flares. The crew transfer vehicle discussed will complete the second half of a Split Mission to Mars. In the Split Mission, a slow, unmanned cargo vehicle, nicknamed the Barge, is sent to Mars ahead of the crew vehicle. Once the Barge is in orbit around Mars, the fast crew vehicle will be launched to rendezvous with the Barge in Mars orbit. The vehicle presented is designed to carry six astronauts for a mission duration of one year. The vehicle uses a chemical propulsion system and a nuclear power system. Four crew modules, similar to the proposed Space Station Common Modules, are used to house the crew and support equipment during the mission. The final design also includes a command module that is shielded to protect the crew during radiation events. Author

N89-15972*# Eagle Engineering, Inc., Houston, TX.
TRANSPORTATION NODE SPACE STATION CONCEPTUAL DESIGN
30 Sep. 1988 211 p
(Contract NAS9-17878)
(NASA-CR-172090; NAS 1.26:172090; EEI-88-207) Avail: NTIS HC A10/MF A01 CSCL 22/2

A number of recent studies have addressed the problem of a transportation node space station. How things would change or what addition facilities would be needed to support a major lunar or Mars initiative is a much often asked question. The support of a lunar base, requiring stacks on the order of 200 metric tons each to land 25 m tons on the lunar surface with reusable vehicles is addressed. The problem of maintaining and reusing large single stage Orbit Transfer Vehicles (OTVs) and single stage lander/launchers in space are examined. The required people and equipment needed, to maintain these vehicles are only vaguely known at present. The people and equipment needed depend on how well the OTV and lander/launcher can be designed for easy reuse. Since the OTV and lander/launcher are only conceptually defined at present, the real maintenance and refurbishment requirements are unobtainable. An estimate of what is needed, based on previous studies and obvious requirements was therefore made. An attempt was made to err on the conservative side. Author

N89-16707*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
OFFICE OF EXPLORATION: EXPLORATION STUDIES TECHNICAL REPORT. VOLUME 2: STUDIES APPROACH AND RESULTS Status Report, FY 1988
BARNEY B. ROBERTS and DAN BLAND Dec. 1988 356 p
(NASA-TM-4075-VOL-2; NAS 1.15:4075-VOL-2) Avail: NTIS HC A16/MF A01 CSCL 03/2

The NASA Office of Exploration has been tasked with defining and recommending alternatives for an early 1990's national decision on a focused program of human exploration of the solar system. The Mission Analysis and System Engineering (MASE) group, which is managed by the Exploration Studies Office at the Johnson Space Center, is responsible for coordinating the technical studies necessary for accomplishing such a task. This technical report describes the process that has been developed in a case study approach. The four case studies that were developed in FY88 include: (1) human expedition to Phobos; (2) human expeditions to Mars; (3) lunar observatory; and (4) lunar outpost to early Mars evolution. The final outcome of this effort is a set of programmatic and technical conclusions and recommendations for the following year's work. Volume 2 describes the case study process, the technical results of each of the case studies, and opportunities for additional study. Included in the discussion of each case study is a description of the mission key features and profile. Mission definition and manifesting are detailed, followed by a description of the mission architecture and infrastructure. Systems concepts for the required orbital nodes, transportation systems, and planetary surface systems are discussed. Prerequisite implementation plans resulting from the synthesized case studies are described and in-depth assessments are presented. Author

N89-17612*# Texas Univ., Austin.
GATEWAY: AN EARTH ORBITING TRANSPORTATION NODE
6 May 1988 124 p
(Contract NGT-21-002-080)
(NASA-CR-184751; NAS 1.26:184751; DR-2) Avail: NTIS HC A06/MF A01 CSCL 22/2

University of Texas Mission Design (UTMD) has outlined the components that a space based transportation facility must include in order to support the first decade of Lunar base buildup. After studying anticipated traffic flow to and from the hub, and taking into account crew manhour considerations, propellant storage, orbital transfer vehicle maintenance requirements, and orbital mechanics, UTMD arrived at a design for the facility. The amount of activity directly related to supporting Lunar base traffic is too high to allow the transportation hub to be part of the NASA Space Station. Instead, a separate structure should be constructed and dedicated to handling all transportation-related duties. UTMD found that the structure (named Gateway) would need a permanent crew of four to perform maintenance tasks on the orbital transfer and

orbital maneuvering vehicles and to transfer payload from launch vehicles to the orbital transfer vehicles. In addition, quarters for 4 more persons should be allocated for temporary accommodation of Lunar base crew passing through Gateway. UTMD was careful to recommend an expendable structure that can adapt to meet the growing needs of the American space program. Author

N89-18507*# Texas Univ., Austin. Space Port Systems.
MOONPORT: TRANSPORTATION NODE IN LUNAR ORBIT Final Report
May 1987 182 p
(Contract NGT-21-002-080)
(NASA-CR-184733; NAS 1.26:184733) Avail: NTIS HC A09/MF A01 CSCL 22/1

An orbital transporation system between the Earth and Moon was designed. The design work focused on the requirements and configuration of an orbiting lunar base. The design utilized current Space Station technologies, but also focused on the specific requirements involved with a permanently manned, orbiting lunar station. A model of the recommended configuration was constructed. In order to analyze Moonport activity and requirements, a traffic model was designed, defining traffic between the lunar port, or Moonport and low Earth orbit. Also, a lunar base model was used to estimate requirements of the surface base on Moonport traffic and operations. A study was conducted to compare Moonport traffic and operations based in low lunar orbit and the L (sub 2) equilibrium point, behind the Moon. The study compared delta-V requirements to each location and possible payload deliveries to low Earth orbit from each location. Products of the Moonport location study included number of flights annually to Moonport, net payload delivery to low Earth orbit, and Moonport storage requirement. Author

N89-18510*# Utah State Univ., Logan.
LUNAR ORBITING PROSPECTOR Final Report
1988 310 p
(Contract NGT-21-002-080)
(NASA-CR-184755; NAS 1.26:184755) Avail: NTIS HC A14/MF A01 CSCL 22/2

One of the prime reasons for establishing a manned lunar presence is the possibility of using the potential lunar resources. The Lunar Orbital Prospector (LOP) is a lunar orbiting platform whose mission is to prospect and explore the Moon from orbit in support of early lunar colonization and exploitation efforts. The LOP mission is divided into three primary phases: transport from Earth to low lunar orbit (LLO), operation in lunar orbit, and platform servicing in lunar orbit. The platform alters its orbit to obtain the desired surface viewing, and the orbit can be changed periodically as needed. After completion of the inital remote sensing mission, more ambitious and/or complicated prospecting and exploration missions can be contemplated. A refueled propulsion module, updated instruments, or additional remote sensing packages can be flown up from the lunar base to the platform. B.G.

N89-18511*# Michigan Univ., Ann Arbor. Dept. of Aerospace Engineering.
CAMELOT 2 Final Report
1988 263 p
(Contract NGT-21-002-080)
(NASA-CR-184731; NAS 1.26:184731) Avail: NTIS HC A12/MF A01 CSCL 22/2

The design parameters of a space vehicle resulting from studies conducted at the University of Michigan are presented. The vehicle is identified as a Circulating Autonomous Mars-Earth Luxury Orbital Transport (CAMELOT). This report documents the results of the current study based on several key changes in the spacecraft systems and layout. Subjects discussed are propulsion, docking, power systems, habitat design, and orbital assembly. NASA

N89-19323# Technische Univ., Berlin (Germany, F.R.). Inst. fuer Luft- und Raumfahrt.
A MODEL FOR THE GEOSTATIONARY ORBITAL INFRASTRUCTURE, SYSTEM ANALYSIS
H. H. KOELLE and N. MILLIN 1 Aug. 1988 35 p
(ILR-MITT-205; ETN-89-93978) Avail: NTIS HC A03/MF A01

The functions and architecture of an infrastructure in the geostationary orbit (GEO) are discussed. A case study of a typical GEO infrastructure as it may develop during the next century was carried out, emphasizing conceptual design and analysis of a subsystem of this GEO infrastructure: the GEO Regional Transportation Company (GRET) envisaged as a commercial enterprise serving the 39 routes within the GEO complex by 10 different types of robots, taxis, and tugs. Results of simulation runs over a 110 yr life cycle produce timelines of several system performance parameters including prices for services within the market scenario assumed, which includes the acquisition and operation of a solar power system with 500 GW output. ESA

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MISSIONS, TETHERS, AND PLATFORMS

Includes descriptions and requirements of missions and tethers onboard the Space Station and platforms that are either co-orbiting with the Space Station, in polar orbit, or in geosynchronous orbit and which are part of the Space Station system.

A89-10964#
OPERATIONAL ENVIRONMENTAL INSTRUMENTATION PROPOSED BY NOAA AND THE INTERNATIONAL COMMUNITY FOR THE NASA AND ESA POLAR ORBITING PLATFORMS
BRUCE H. NEEDHAM (NOAA, Washington, DC) IN: International Symposium on Remote Sensing of Environment, 21st, Ann Arbor, MI, Oct. 26-30, 1987, Proceedings. Volume 1. Ann Arbor, MI, Environmental Research Institute of Michigan, 1987, p. 551-559.

In the mid-1990's the National Aeronautics and Space Aministration (NASA) and the European Space Agency (ESA) each plan to launch serviceable polar orbiting platforms as part of the International Space Station program. The National Oceanic and Atmospheric Administration (NOAA) is planign to utilize the NASA and ESA polar orbiting platforms to carry its' operational instruments for environmental remote sensing as a follow-on to the NOAA K, L, M series of operational polar orbiting satellites. Author

A89-11125*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
SCIENTIFIC MISSIONS FOR EARTH ORBITAL TETHER SYSTEMS
WILLIAM J. WEBSTER, JR. (NASA, Goddard Space Flight Center, Greenbelt, MD) (NASA, AIAA, and PSN, International Conference on Tethers in Space, Arlington, VA, Sept. 17-19, 1986) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 25, July-Aug. 1988, p. 299-303. Previously cited in issue 03, p. 304, Accession no. A87-14081. refs

A89-11823* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
U.S. SPACE STATION PLATFORM - CONFIGURATION TECHNOLOGY FOR CUSTOMER SERVICING
JOSEPH A. DEZIO and BARBARA A. WALTON (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Space Station automation III; Proceedings of the Meeting, Cambridge, MA, Nov. 2-4, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1987, p. 152-157.

Features of the Space Station coorbiting and polar orbiting platforms (COP and POP, respectively) are described that will allow them to be configured optimally to meet mission requirements and to be assembled, serviced, and modified on-orbit. Both of these platforms were designed to permit servicing at the Shuttle using the remote manipulator system with teleoperated end

effectors; EVA was planned as a backup and for unplanned payload failure modes. Station-based servicing is discussed as well as expendable launch vehicle-based servicing concepts. K.K.

A89-11890
HOSTILE HIGH ENERGY VISIBLE LASER ENVIRONMENT PROVIDING DESTRUCTION OF OPTICAL SIGNAL IN IMAGING SYSTEMS
J. R. PALMER (Alabama, University, Huntsville) IN: Optical devices in adverse environments; Proceedings of the Meeting, Cannes, France, Nov. 19, 20, 1987. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 130-174. refs

The amounts of pulsed or CW laser radiation sufficient to permanently damage various types of optical imaging systems are calculated theoretically, with an emphasis on systems designed to operate in the IR. The general physical principles on which the estimates are based are reviewed; the formulations for the individual computations are described in detail; and results are presented in extensive tables for metallic surfaces (Cu, Au, and Ag), thin-film-coated optics, MTF analyses, and thermal shock in coated and metallic reflective optics. The sensitivity of many optical systems to relatively low light levels is indicated, and it is pointed out that collection-system optics can also be affected if the collection system itself (rather than the detector) is damage-prone. T.K.

A89-12649
COUPLING OF TETHER MODES WITH SUB-SATELLITE ATTITUDE MOTION
A. H. VON FLOTOW and N. M. WERELEY (MIT, Cambridge, MA) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 411-424. refs
(AAS PAPER 87-433)

The attitude oscillations of a tethered subsatellite are considered as well as the oscillation of an internal fuel slosh mode, uniform tether stretch, and lateral tether motion discretized by a sequence of assumed modes. It is shown that tether-aligned thrusting is nonconservative and may lead to dynamic instability. This instability was demonstrated using simple models with reasonable parameter values. K.K.

A89-12650
MAGNETICALLY INDUCED LIBRATIONS IN CONDUCTING TETHERS
S. BERGAMASCHI and B. QUADRELLI (Padova, Universita, Padua, Italy) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 441-453. refs
(Contract CNR-86,022)
(AAS PAPER 87-435)

The purpose of this paper is to investigate the motion of a conducting tether, caused by the interaction of the electric current flowing in it with the Earth magnetic field. Two different models are used. In the first, orbital effects are taken into account and the tether is rigid; in the second, the orbit is neglected and elastic vibrations are investigated. The equations of motion are integrated and results are given for different current intensities and frequencies, as well as for different orbits. Author

A89-12651* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
A LOW EARTH ORBIT SKYHOOK TETHER TRANSPORTATION SYSTEM
PAUL A. PENZO (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 455-468. refs
(AAS PAPER 87-436)

This paper discusses the design concept of a structure, called the Skyhook Tether Transportation System (STTS) which may be used to transport mass to higher or lower orbits or to capture objects from higher or lower orbits. An analysis is presented for the possibility of the STTS to perform the function of transporting masses suborbitally, capturing the objects, and then releasing them to a higher orbit, the GEO, the moon, or for an escape. It is shown that, although the possibility of such a system is limited by the tether strength, even a modest system can yield considerable benefits in propellant savings if it is used in combination with chemical propulsion. I.S.

A89-13419
COLUMBUS ON-BOARD SOFTWARE
M. IRVING and J. LEE (Logica Space and Defence Systems, Ltd., London, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 41, Oct. 1988, p. 483-488. Research supported by MBB-Erno Raumfahrttechnik GmbH.

The Columbus on-board software and hardware system design is described, considering the Man Tended Free Flyer (MTFF) subsystems and payloads. The payloads that the MTFF will contain are designed to perform experiments in material science, fluid physics, life sciences, and other related areas. The system mission management (SMM) and software are outlined. SMM requirements fall into the following categories: system supervision, mission management, system monitoring, and fault management. K.K.

A89-14762
DYNAMICS OF TETHERED SPACE SYSTEMS [DINAMIKA KOSMICHESKIKH TROSOVYKH SISTEM]
V. V. BELETSKII IN: Mechanics and scientific-technological progress. Volume 1. Moscow, Izdatel'stvo Nauka, 1987, p. 226-241. In Russian. refs

The history and the current status of theoretical and applied research in the field of tethered space systems are briefly reviewed. In particular, attention is given to equations of motion of an orbital tethered system, stationary configurations in a gravitational field, systems with weightless and ponderable tethers, and a tethered system deployment model. The discussion also covers pendulum motions of a tethered system, modes and frequencies of small vibrations of a radial tethered system, stationary motion and stability of an atmospheric probe, and an electromagnetic orbital tethered system. V.L.

A89-15150#
TETHERS - A KEY TECHNOLOGY FOR FUTURE SPACE FLIGHT? [TETHERS - EEN SLEUTELTECHNOLOGIE IN DE RUIMTEVAART VAN MORGEN?]
M. P. M. VAN ROOZENDAAL (Centrale Organisatie voor Toegepast-Natuurwetenschappelijk Onderzoek, Instituut voor Produktonwikkeling TNO, Netherlands) Ruimtevaart, vol. 37, Aug. 1988, p. 16-24. In Dutch.

The current development status of tethered spacecraft is surveyed, with an emphasis on projects related to the International Space Station. The history of tether concepts is briefly recalled, and consideration is given to the use of tethers to release payloads for reentry or orbital transport, power generation with electrodynamic tethers, tether-spacecraft dynamics, the selection of high-strength lightweight materials for the tether itself, and the planned scientific missions of the Shuttle-deployable TSS-1 and TSS-2 tethered ionosphere probes. In the Space Station context, it is estimated that the use of tethers to release the Space Shuttle and waste containers for reentry and to release OTVs for flight to higher altitudes could yield savings of up to 89,000 kg of fuel per year (for a cost savings of $1.1-2.1 billion over an 11-year period). T.K.

A89-15848* Fairchild Space and Electronics Co., Germantown, MD.
DUAL KEEL SPACE STATION PAYLOAD POINTING SYSTEM DESIGN AND ANALYSIS FEASIBILITY STUDY
TOM SMAGALA, BRIAN F. CLASS (Fairchild Space Co. Germantown, MD), FRANK H. BAUER, and DEBORAH A. LEBAIR (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Acquisition, tracking, and pointing II; Proceedings of the Meeting,

Los Angeles, CA, Jan. 14, 15, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 2-10. refs

A Space Station attached Payload Pointing System (PPS) has been designed and analyzed. The PPS is responsible for maintaining fixed payload pointing in the presence of disturbance applied to the Space Station. The payload considered in this analysis is the Solar Optical Telescope. System performance is evaluated via digital time simulations by applying various disturbance forces to the Space Station. The PPS meets the Space Station articulated pointing requirement for all disturbances except Shuttle docking and some centrifuge cases. Author

A89-16167#
EXTENSIONAL OSCILLATIONS OF TETHERED SATELLITE SYSTEMS
A. K. MISRA (McGill University, Montreal, Canada) and V. J. MODI (British Columbia, University, Vancouver, Canada) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 11, Nov.-Dec. 1988, p. 594-597. Previously cited in issue 23, p. 3420, Accession no. A86-47942. refs
(Contract NSERC-A-0967; NSERC-A-2181)

A89-16504*# Martin Marietta Corp., Denver, CO.
TETHERED VERSUS ATTACHED CRYOGENIC PROPELLANT STORAGE AT SPACE STATION
DALE A. FESTER, L. KEVIN RUDOLPH, and ERLINDA R. KIEFEL (Martin Marietta Corp., Astronautics Group, Denver, CO) International Symposium on Space Technology and Science, 16th, Sapporo, Japan, May 22-27, 1988, Paper. 19 p. refs
(Contract NAS9-17422)

The space-based orbital transfer vehicle will require a large cryogenic fuel storage facility at the Space Station. An alternative to fuel storage on-board the Space Station is on a tethered orbital refueling facility (TORF) which is separated from the Space Station by a sufficient distance to induce a gravity gradient to settle the propellants. Overall costs and benefits of a particular tethered facility design have been defined relative to a representative zero-gravity facility on the Space Station. Results indicate that the TORF hardware and operations costs are roughly 40 percent higher than the comparable zero-g facility costs. The cost difference is negligible when compared to the launch cost of the fuel over the facility 10-year lifetime. Author

A89-17682*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
THE EARTH OBSERVING SYSTEM
GERALD A. SOFFEN (NASA, Goddard Space Flight Center, Greenbelt, MD) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 9 p.
(IAF PAPER 88-114)

NASA's Earth Observing System (EOS) is a prospective program for earth observation from space using various unmanned, sun-synchronous polar orbit sensor platforms in conjunction with the Space Station to conduct measurements over a period of 15 years. The most important instruments will be the Moderate-Resolution Imaging Spectrometer, the High-Resolution Imaging Spectrometer, a large-area coverage SAR, the Laser Atmospheric Wind Sounder, the Atmospheric IR Sounder, and a Geodynamics and Laser-Ranging System. O.C.

A89-17684#
THREE-DIMENSIONAL OBSERVATION BY MEANS OF TETHERED ANTENNAE
A. MOCCIA and S. VETRELLA (Napoli, Universita, Naples, Italy) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 14 p. Research supported by the Italian Space Agency and MPI. refs
(IAF PAPER 88-118)

A digital simulation is conducted for a SAR interferometric system of novel configuration, in which two antennae are respectively held at different orbital altitudes by a main space station and a tether-connected subsatellite. The station transmits radar pulses, and both antennas receive return signals. Attention is given to a specific mission specification that illustrates the accuracy thus achievable in terrain mapping tasks, with a view to the development of future real-time space cartographic services able to operate in adverse weather and nocturnally as well as diurnally. O.C.

A89-17771#
AUTONOMOUS GEOSTATIONARY STATIONKEEPING SYSTEM OPTIMIZATION AND VALIDATION
P. MAUTE, B. BLANCKE, J. PH. JAHIER (Aerospatiale, Cannes, France), and F. ALBY (CNES, Toulouse, France) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p.
(IAF PAPER 88-327)

The results of an on-going joint CNES-Aerospatiale study designed to optimize and qualify a geostationary station keeping system using earth, sun, and Polaris sensor measurements are presented. The main system features and the optimization process are considered. The validation method, based on the implementation of the on-board software on a microprocessor interfaced with a computer in charge of a system environment simulation, is described. K.K.

A89-18314#
COLUMBUS LOGISTICS PROGRAM
MIKE C. ATTWOOD and STEFANOS MELISSOPOULOS (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 11 p.
(AIAA PAPER 88-4737)

An account is given of the logistics scenario envisioned by ESA for the Man-Tended Free Flyer and Attached Pressurized Module elements of Columbus, in light of current Columbus configuration concepts and the planned interface of Columbus with Hermes. The resupply infrastructure identified covers the spectrum from provision of off-line repair of units at a manufacturing facility via ground/orbit transport to on-orbit storage until utilization is called for. A Centralized Logistics Facility will coordinate and control all required logistics support activities. O.C.

A89-19916*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SPACE VEHICLE GLOW AND ITS IMPACT ON SPACECRAFT SYSTEMS
H. B. GARRETT, A. CHUTJIAN, and S. GABRIEL (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 25, Sept.-Oct. 1988, p. 321-340. refs

Spacecraft glow poses a contamination threat to low orbital altitude optical sensor systems. The complexity of the phenomena entails a multifaceted approach to system design for vehicle glow minimization. In the case of Space Shuttle cloud glow, which involves line and band emission, filtering and careful optical sensor wavelength selection may also prove useful; Space Shuttle thruster glow mitigation entails the limitation of thruster firings during sensor operations. Careful selection of instrument baffle materials and coatings, as well as control of surface temperatures, are recommended as ways of limiting glow impact for instruments directed in the direction of vehicle movement. O.C.

A89-21769* California Univ., Los Angeles.
BEAM-PLASMA INTERACTIONS IN SPACE EXPERIMENTS - A SIMULATION STUDY
P. L. PRITCHETT (California, University, Los Angeles) and R. M. WINGLEE (Colorado, University, Boulder) (Society of Geomagnetism and Earth, Planetary and Space Sciences, Inoue Foundation for Science and the Telecommunications Advancement, and URSI, Workshop on Active Experiments in Space, Kyoto, Japan, Oct. 19, 20, 1987) Journal of Geomagnetism and Geoelectricity (ISSN 0022-1392), vol. 40, no. 10, 1988, p. 1235-1256. refs

(Contract NAGW-78; NAGW-91; NSG-7287; NSF ATM-85-21125; F19628-88-K-0022; F19628-85-K-0027)

The plasma environment in the vicinity of a spacecraft during the injection of dense electron beams is studied using a two-dimensional, isolated-system electrostatic simulation model. The dependence of the beam stagnation time on the beam width and energy is examined. It is found that the relative size of the beam stagnation time and the ambient-plasma response time determines the environment of the spacecraft. The case of cross-field injection with beam stagnation time greater than plasma response time is discussed in detail. Also, the nature of the beam properties, plasma response, and wave spectra are considered. R.B.

A89-23255
EMPLOYING SPACE TETHERS

IAN PARKER Space (ISSN 0267-954X), vol. 4, Mar.-Apr. 1988, p. 28, 29, 31.

Research concerning the development and applications of space tethers is reviewed. The TSS-1 mission to study tether dynamics by deploying a satellite 20 km above the Space Shuttle using a 2-mm thick tether and the TSS-2 mission to study the upper atmosphere are discussed. The possible uses of tethers with the Space Station are examined, including reentry, boosting, and energy applications. Also, the creation of artificial gravity by rotating a spacecraft tethered to a mass and the possibility of using tethers to launch satellites from orbital towers are considered. R.B.

A89-23540
MOTION STEREO AND EGO-MOTION COMPLEX LOGARITHMIC MAPPING (ECLM)

SANDRA L. BARTLETT and RAMESH JAIN (Michigan, University, Ann Arbor) IN: Digital and optical shape representation and pattern recognition; Proceedings of the Meeting, Orlando, FL, Apr. 4-6, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 138-145. refs
(Contract NSF MCS-82-19739; F49620-82-C-0089)

Ego-motion Complex Logarithmic Mapping (ECLM) employs approximate ego-motion information obtainable in such applications (which require object-recognition, depth-determination, and dynamic scene-segmentation) as autonomous-navigation vehicles, space station construction, and robot arm control, to choose the origin of the mapping. This choice facilitates the use of important characteristics of optical flow without the onerous requirement to calculate the flow. An evaluation is made of the performance of point-, line-, and region algorithms in ECLM space, as well as of the ways in which they can be used for depth determination. O.C.

A89-24674
CONCEPTS FOR CRYSTALLIZATION OF ORGANIC MATERIAL UNDER MICROGRAVITY

A. PLAAS-LINK (Intospace GmbH, Hanover, Federal Republic of Germany) and J. CORNIER Applied Microgravity Technology (ISSN 0931-9530), vol. 1, July 1988, p. 123-132. refs

Methods for growing crystals of organic material in microgravity are discussed. Methods for protein crystal growth on earth are reviewed, including the vapor diffusion, dialysis, liquid/liquid diffusion, and temperature gradient techniques. The advantages of protein crystal growth in microgravity are considered and the experiments performed during Spacelab I (Littke and John, 1986) and on the Space Shuttle (De Lucase et al., 1986) are described. Plans for future research are examined, including the Spacelab and the ESA Eureca platform. The Crystallization of Organic Substances In Microgravity for Applied research concept, which makes it possible to use all of the major crystallization techniques in a microgravity environment, is discussed in detail. R.B.

A89-24708
THE FIGURE-OF-8 LIBRATIONS OF THE GRAVITY GRADIENT PENDULUM AND MODES OF AN ORBITING TETHER

PETER J. MELVIN (U.S. Navy, Naval Research Laboratory, Washington, DC) Quarterly of Applied Mathematics (ISSN 0033-569X), vol. 46, Dec. 1988, p. 637-663. Research supported by the U.S. Navy and SDIO. refs

An algorithm is presented for the Hill-Poincare analytical continuation of the out-of-plane normal mode of the gravity gradient pendulum. The Poincare-Lindstedt solution employs 17 Poisson series and 24 recursion relations; it was evaluated to the 50th order on a CRAY. The trajectories of the nonlinear normal modes are figures-of-8 on the unit sphere which can be computed nearly to the orbit normal. Numerical integrations indicate further that initial conditions computed at the nadir can be used to generate figures-of-8 over the pole, that the single hemispherical figures-of-8 appear to be stable at large amplitudes, and that the gravity gradient pendulum has chaotic solutions. A theory is developed for the linear normal modes of a tethered satellite, and the eigenvalues are found for the rosary tether. Author

A89-25088*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
DESIGN OPTIONS AND ANALYSIS OF VARIABLE GRAVITY SYSTEMS IN SPACE

PAUL A. PENZO and RODICA IONASESCU (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 11 p. refs
(AIAA PAPER 89-0100)

Design options for tethered systems which can produce a variable gravity living environment in space are discussed. Parameters of rotating systems are reviewed, and early studies of rotating systems are recalled. Artificial gravity configurations are shown and their individual advantages and disadvantages are examined. C.D.

A89-25094*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ENHANCING AEROSPACE SYSTEMS AUTONOMY THROUGH PREDICTIVE MONITORING

RICHARD J. DOYLE, SUZANNE M. SELLERS, and DAVID J. ATKINSON (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 12 p. refs
(AIAA PAPER 89-0107)

The quick and reliable detection of anomalous behavior in aerospace systems is addressed. Ways to adjust nominal sensor value expectations dynamically, taking into account the changing operating context of the system, are considered. How to utilize sensors selectively, determining which subset of the available sensors to use at any given time to verify nominal operation efficiently without processing a prohibitive amount of data, is examined. C.D.

A89-25211*# NASA Space Station Program Office, Reston, VA.
SPACE STATION FREEDOM AS AN EARTH OBSERVING PLATFORM

RICHARD E. SNYDER and VINCENT J. BILARDO, JR. (NASA, Space Station Freedom Program Office, Reston, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 13 p. refs
(AIAA PAPER 89-0251)

The Space Station manned base is discussed, focusing on the use of the base as a science platform for earth observation. The program elements of the Space Station are described, including the manned base, the international elements, the Polar Platform, and the Man-tended Frequent Flyer. The accommodation and operational requirements for the earth observation payloads are examined. Candidate missions for the manned base earth observation program are presented, including observations of tropical regions, the Tropical Rainfall Measuring Mission, the tropical regions imaging spectrometer, the Earth Radiation Budget Experiment, and commercial remote sensing. R.B.

A89-25408#
UTILIZATION OF THE U.S. LABORATORY

EUGENE G. COWART (Boeing Aerospace, Huntsville, AL) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p.
(AIAA PAPER 89-0507)

The U.S. Laboratory, which is being developed for the Space Station is examined. The processes for the development, integration, and construction of payloads for the laboratory are discussed. The customer utilization program to work with customers in the development and integration of payloads is outlined. Also, the laboratory support equipment, customer resources, payloads, and experiments under consideration are listed. R.B.

A89-25409*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
SPACE STATION UTILIZATION FOR THE ASTROMETRIC TELESCOPE FACILITY
KENJI NISHIOKA, DAVID C. BLACK, GEORGE D. GATEWOOD, and EUGENE H. LEVY (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(AIAA PAPER 89-0510)

It is shown how it is possible for the Astrometric Telescope Facility (ATF) to utilize the Space Station Freedom as an attached payload by complying with changes in the Station concept and schedule. The ability of the station to accommodate ATF's firm requirements is also addressed. The main factors that led the ATF to utilize the Space Station Freedom are the Station's relative orbital stability and longevity, the availability of maintenance and repair services, and the provision of utilities. K.K.

A89-27221
DESIGN OF THE ST DATA MANAGEMENT FACILITY CATALOG
STEPHEN H. LUBOW (Space Telescope Science Institute; Johns Hopkins University, Baltimore, MD) IN: Astronomy from large databases: Scientific objectives and methodological approaches; Proceedings of the Conference, Garching, Federal Republic of Germany, Oct. 12-14, 1987. Garching, Federal Republic of Germany, European Southern Observatory, 1988, p. 373-378. refs

The Space Telescope (ST) Data Management Facility (DMF) is an interim data archive for ST data. The DMF catalog consists of summary information about ST observations and associated data. The catalog contains an observation index which is used to provide information about successfully proposed, uninitiated observations, as well as information about completed observations. In the latter case, the observation index includes information sufficient to locate the actual data on optical disk. The catalog will also contain information about calibration and engineering parameters. Potential catalog users include archival researchers, ST proposers and users, instrument scientists, and engineers. Several design issues and decisions are discussed. These include the use of a commercial relational database system, the choice among existing relational systems, use of standard interfaces, the structure of the observation index, and the flow of data into the catalog. Author

A89-27830
SPACEHAB - A MULTIPURPOSE FACILITY FOR LIFE SCIENCES
CHESTER M. LEE (Spacehab, Inc., Seattle, WA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 7 p.
(SAE PAPER 881028)

Spacehab, a pressurized habitable living compartment designed to be mounted in the Shuttle Orbiter cargo bay, is described and illustrated with drawings. Spacehab is a metal cylinder facility that can accomodate and support additional life-science experiments, since both Spacehab and Spacelab could be flown on the same mission. Using Spacehab could reduce costs and lead time for payload integration, mission planning, and preparation. The facility could also be used as a Space Station safe haven/infirmary, an advanced-systems testbed, or a permanent isolated X-ray facility. A.A.F.

A89-28125* Stanford Univ., CA.
HIGH-ENERGY FACILITY DEVELOPMENT PLAN
ARTHUR B. C. WALKER, JR. (Stanford University, CA), W. T. ROBERTS, and J. R. DABBS (NASA, Marshall Space Flight Center, Huntsville, AL) Solar Physics (ISSN 0038-0938), vol. 118, no. 1-2, 1988, p. 365-371. refs
(Contract NSG-5131)

Approaches to the deployment of instruments for the study of high-energy solar emissions alone or in conjunction with other solar instruments are considered. The Space Station has been identified as the preferred mode for the deployment of the Advanced Solar Observatory, and it is suggested that a proposed High-Energy Facility could be on a coorbiting platform. The implementation plan for the High-Energy Facility involves the definition of the interface structures required to mount the facility instruments to the Space Station and the development of hard X-ray and gamma-ray imaging, spectroscopic, and polarimetric instruments. R.R.

A89-28950* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
PROSPECTS FOR A CONTAMINATION-FREE ULTRAVACUUM FACILITY IN LOW-EARTH ORBIT
ROBERT J. NAUMANN (NASA, Marshall Space Flight Center, Huntsville, AL) Journal of Vacuum Science and Technology A (ISSN 0734-2101), vol. 7, Jan.-Feb. 1989, p. 90-99. refs

The old concept of using the wake of a spacecraft to obtain an ultrahigh vacuum is revisited. A wakeshield can be configured so that a surface of interest does not subtend any walls that could become contaminated, thus it should be possible to achieve a contamination-free, ultrahigh vacuum capability with infinite pumping speed even in the presence of high heat loads and moderate gas loads. This papar analyzes the conceptual design for a Space Ultravacuum Research Facility (SURF), both in a shuttle-attached mode and as a free flyer. It is shown that even in the shuttle-attached mode, it should be possible to obtain vacuum levels equivalent to 10 to the -9th to 10 to the -10th Torr with O and N2 as the primary constituents. As a free flyer the SURF will be limited primarily by the gas load from the process being performed. For chemical beam epitaxy it is shown that equivalent vacuum levels of 10 to the -14th Torr should be possible at 300 km. Author

A89-31876*# National Aeronautics and Space Administration, Washington, DC.
OUTER ATMOSPHERIC RESEARCH USING TETHERED SYSTEMS
JOHN L. ANDERSON (NASA, Washington, DC) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, Mar.-Apr. 1989, p. 66-71. Previously cited in issue 07, p. 1032, Accession no. A88-22512. refs

A89-31877#
TETHER SATELLITE POTENTIAL FOR RAREFIED GAS AERODYNAMIC RESEARCH
F. C. HURLBUT (California, University, Berkeley) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, Mar.-Apr. 1989, p. 72-79. Previously cited in issue 07, p. 966, Accession no. A88-22513. refs

A89-31878*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
ENGINEERING TETHERED PAYLOADS FOR MAGNETIC AND PLASMA OBSERVATIONS IN LOW ORBIT
WILLIAM J. WEBSTER, JR. (NASA, Goddard Space Flight Center, Greenbelt, MD) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, Mar.-Apr. 1989, p. 80-84. Previously cited in issue 07, p. 1052, Accession no. A88-22515. refs

A89-31941* Colorado Univ., Boulder.
TOWARD A COMPLETE EOS DATA AND INFORMATION SYSTEM
ROBERT R. P. CHASE (Colorado, University, Boulder) IEEE Transactions on Geoscience and Remote Sensing (ISSN 0196-2892), vol. 27, March 1989, p. 125-131. refs
(Contract NAGW-946; NAGW-1121; NAGW-1191)

Based on NASA EOS data panel analyses, an architectural concept is described in terms of elemental composition, top-level functions, and external and internal interfaces. This concept has been evaluated through the use of realistic user-generated scenarios consistent with existing plans for the 1990s and the Space Station. Developmental approaches for the requisite EOS data and information system are presented and a hybrid methodology for implementing this system is discussed. I.E.

N89-10264*# Alabama Univ., Huntsville. Dept. of Physics.
COMPACT IMAGING SPECTROMETER FOR INDUCED EMISSIONS Final Technical Report, 31 Mar. 1986 - 1 Feb. 1988
DOUGLAS G. TORR Sep. 1988 20 p
(Contract NAG8-060)
(NASA-CR-183187; NAS 1.26:183187) Avail: NTIS HC A03/MF A01 CSCL 14B

On the basis of spectral measurements made from the Space Shuttle and on models of the possible Space Station external environment, it appears likely that, even at the planned altitudes of Space Station, photon emissions will be induced. These emissions will occur to some degree throughout the ultraviolet-visible-infrared spectrum. The emissions arise from a combination of processes including gas phase collisions between relatively energetic ambient and surface emitted or re-emitted atoms or molecules, where the surface raises some species to excited energy states. At the present time it is not possible to model these processes or the anticipated intensity levels with any accuracy, as a number of fundamental parameters needed for such calculations are still poorly known or unknown. However, it is possible that certain spectral line and band features will exceed the desired goal that concomitant emissions not exceed the natural zodiacal background. Also, in the near infrared and infrared, it appears that this level will be exceeded to a significant degree. Therefore it will be necessary to monitor emission levels in the vicinity of Space Station, both in order to establish the levels and to better model the environment. A small spectrometer is briefly described which is suitable for monitoring the spectrum from 1200 A to less than or equal to 12,000 A. The instrument uses focal plane array detectors to image this full spectral range simultaneously. The spectral resolution is 4 to 12 A, depending on the portion of the wavelength range. Author

N89-10931*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
SPACE SCIENCE/SPACE STATION ATTACHED PAYLOAD POINTING ACCOMMODATION STUDY: TECHNOLOGY ASSESSMENT WHITE PAPER
RICHARD Y. LIN, KENNETH E. MANN, ROBERT A. LASKIN, and SAMUEL W. SIRLIN 15 Dec. 1987 82 p
(Contract NAS7-918)
(NASA-CR-182735; NAS 1.26:182735; JPL-PUBL-87-43) Avail: NTIS HC A05/MF A01 CSCL 22B

Technology assessment is performed for pointing systems that accommodate payloads of large mass and large dimensions. Related technology areas are also examined. These related areas include active thermal lines or power cables across gimbals, new materials for increased passive damping, tethered pointing, and inertially reacting pointing systems. Conclusions, issues and concerns, and recommendations regarding the status and development of large pointing systems for space applications are made based on the performed assessments. Author

N89-10934*# Control Dynamics Co., Huntsville, AL.
TETHER APPLICATIONS Interim Report
Nov. 1986 94 p
(Contract NAS8-35835)
(NASA-CR-179392; NAS 1.26:179392) Avail: NTIS HC A05/MF A01 CSCL 22B

For a range of tether lengths, end masses, and orbits, tether deployment concepts were defined and/or analyzed from the Orbiter for steady state/dynamic and up/down deployments and from circular/elliptical orbits. Orbits were defined and/or analyzed for end mass releasing concepts with steady state and dynamic releases taking into account tether and end mass motion before and after release. For a range of tether lengths, end masses, and orbits, tether retrieving or disposing concepts were defined and/or analyzed for both reusable and disposable tethers. Tether programs were installed or updated on the MSFC VAX 11/780 computer. Author

N89-11504# Los Alamos National Lab., NM. Chemistry and Laser Sciences Div.
HIGH ENERGY-INTENSITY ATOMIC OXYGEN BEAM SOURCE FOR LOW EARTH ORBIT MATERIALS DEGRADATION STUDIES
J. B. CROSS and N. C. BLAIS 1988 14 p Presented at the 16th International Symposium on Rarefied Gas Dynamics, Pasadena, Calif., 11 Jul. 1988
(Contract W-7405-ENG-36)
(DE88-014316; LA-UR-88-2188; CONF-880781-1) Avail: NTIS HC A03/MF A01

A high intensity (10 to the 19th O-atoms/s-sr) high energy (5 eV) source of oxygen atoms has been developed that produces a total fluence of 10 to the 22d O-atoms/sq cm in less than 100 hours of continuous operation at a distance of 15 cm from the source. The source employs a CW CO2 laser sustained discharge to form a high temperature (15,000 K) plasma in the throat of a 0.3-mm diameter nozzle using 3 to 8 atmospheres of rare gas/O2 mixtures. Visible and infrared photon flux levels of 1 watt/sq cm have been measured 15 cm downstream of the source while vacuum UV (VUV) fluxes are comparable to that measured in low earth orbit. The reactions of atomic oxygen with kapton, Teflon, silver, and various coatings have been studied. The oxidation of kapton (reaction efficiency = 3x10 to the -24 cm + or - 50 percent) has an activation energy of 0.8 Kcal/mole over the temperature range of 25 to 100 C at a beam energy of 1.5 eV and produces low molecular weight gas phase reaction products (H2O, NO, CO2). Teflon reacts with approx 0.1 to 0.2 efficiency to that of kapton at 25 C and both surfaces show a ruglike texture after exposure to the O-atom beam. Angular scattering distribution measurements of O-atoms show a near cosine distribution from reactive surfaces indicating complete accommodation of the translational energy with the surface while a nonreactive surface (nickel oxide) shows specular-like scattering with 50 percent accommodation of the translational energy with the surface. A technique for simple on orbit chemical experiments using resistance measurements of coated silver strips is described. DOE

N89-12048* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
GAS PARTICLE RADIATOR Patent
DONALD L. CHUBB, inventor (to NASA) 13 Sep. 1988 5 p Filed 9 Oct. 1986 Supersedes N87-15452 (25 - 07, p 905)
(NASA-CASE-LEW-14297-1; US-PATENT-4,770,232; US-PATENT-APPL-SN-917125; US-PATENT-CLASS-165-41; US-PATENT-CLASS-165-904; US-PATENT-CLASS-126-443; US-PATENT-CLASS-126-901) Avail: US Patent and Trademark Office CSCL 14/2

A gas particle radiator adapted to operate in a microgravity space environment having a transparent boundary which transmits energy in the infrared spectrum, and a gas particle mixture that yields high absorption and emittances are described.
Official Gazette of the U.S. Patent and Trademark Office

N89-12396# National Aerospace Lab., Amsterdam (Netherlands). Space Div.
DEVELOPMENT OF AN OPTICAL DIAGNOSTIC INSTRUMENT. PART 1: EXECUTIVE SUMMARY Final Report

D. VANDENASSEM and R. H. HUIJSER 15 Jun. 1987 43 p (Contract ESA-5188/82-NL-HP(SC); ESA-6533/85-NL-IW(SC); NIVR-423-02405-N)
(NLR-TR-87079-U-PT-1; B8817853-PT-1; ETN-88-93383; AD-B122239L) Avail: NTIS HC A03/MF A01

An optical diagnostic instrument for fluid physics research in the microgravity environment of a space laboratory is presented. The instrument offers a whole field observation system with a Schlieren overlay combined with a local narrow field observation capability, the stake system. The latter allows for operation of a variety of optical instruments, of which two types were evaluated in a test setup: an equal path interferometer and a moire deflectometer. The development of the narrow field stake system with its accomodation capability of easily exchangeable optical diagnostics is described. The whole field Schlieren system and stake system performance were assessed experimentally. A design for a flight instrument suited for accomodation in a space laboratory is given. ESA

N89-12606*# Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.).
CONTROL OF THE INDUCED MICROGRAVITY ENVIRONMENT OF THE MAN TENDED FREE FLYER (MTFF)
JUERGEN SCHLUND *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 289-307 1988
Avail: NTIS HC A21/MF A01 CSCL 22/1

Induced disturbance sources have been identified on board the Man Tended Free Flyer (MTFF). Vibration responses at sensitive payload/spacecraft interfaces have been predicted by the application of an empirically found spacecraft dynamic transfer function. Vibrations from fluid loops (Freon, water) and of reaction wheels are assessed to be the main contributors to the induced microgravity environment. The expected payload acceleration response amplitudes presented here are more than one hundred times higher than the admissible values given by the MTFF system requirement, not considering the structural striction-friction effects which could be avoided by appropriate design. Real responses will be significantly lower because the derivation of excitation and transmission functions are based on worst case assumptions. The results indicate that future activities must be concentrated on equipment design improvement and the implementation of vibration reduction along the disturbance transmission path. The activities must be accompanied by early equipment and assembly development tests and transmissibility measurements with the integrated spacecraft engineering and structural models in order to improve the accuracy of payload response predictions. Author

N89-14902*# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Aerospace Engineering.
CONTROL OF THE FLEXIBLE MODES OF AN ADVANCED TECHNOLOGY GEOSTATIONARY PLATFORM Abstract Only
DIANE V. DEWALT *In* Hampton Inst., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988 p 50 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 22/2

A controls analysis is conducted on an advanced technology geostationary platform. This spacecraft is a large flexible structure with a payload of Earth-sensing instruments which will collect data from Earth's oceans, land, and atmosphere as a part of the bold initiative mission to Planet Earth proposed by NASA. This program will provide a collection of data from a family of spacecraft in both low-Earth orbit and geostationary orbit, which will afford a global definition of the Earth as a system with the capability to predict future events resulting from human and natural forces. The platform concept studied here is a large flexible structure with a payload of eighteen instruments. Because the platform is in geostationary orbit, these instruments have sensitive pointing accuracy requirements, in the range of 0.1 to 0.0001 degrees, which must be satisfied. The structure housing the instruments is large and flexible with characteristic low natural frequencies, so active control is necessary for vibration suppression. Author

N89-15000*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
PHYSICS OF WINDBLOWN PARTICLES
RONALD GREELEY, RODMAN LEACH, JOHN R. MARSHALL, BRUCE WHITE, JAMES D. IVERSEN, WILLIAM G. NICKLING, DALE GILLETTE, and MICHAEL SORENSEN (Aarhus Univ., Denmark) *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 29 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 03/2

A laboratory facility proposed for the Space Station to investigate fundamental aspects of windblown particles is described. The experiments would take advantage of the environment afforded in earth orbit and would be an extension of research currently being conducted on the geology and physics of windblown sediments on earth, Mars, and Venus. Aeolian (wind) processes are reviewed in the planetary context, the scientific rational is given for specific experiments to be conducted, the experiment apparatus (the Carousel Wind Tunnel, or CWT) is described, and a plan presented for implementing the proposed research program. Author

N89-15001*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
PARTICLE FORMATION AND INTERACTION
STEVEN SQUYRES, GEORGE J. CORSO, LYNN D. GRIFFITHS, IAN D. R. MACKINNON, JOHN R. MARSHALL, JOSEPH A. NUTH, III, BRAD WERNER, and JOHN WOLFE (San Jose State Univ., Calif.) *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 4 p Nov. 1987 Previously announced as N86-27139
Avail: NTIS HC A09/MF A01 CSCL 03/2

A wide variety of experiments can be conducted on the Space Station that involve the physics of small particles of planetary significance. Processes of interest include nucleation and condensation of particles from a gas, aggregation of small particles into larger ones, and low velocity collisions of particles. All of these processes could be investigated with a general purpose facility on the Space Station. The microgravity environment would be necessary to perform many experiments, as they generally require that particles be suspended for periods substantially longer than are practical at 1 g. Only experiments relevant to planetary processes will be discussed in detail here, but it is important to stress that a particle facility will be useful to a wide variety of scientific disciplines, and can be used to address many scientific problems. Author

N89-15018*# Massachusetts Inst. of Tech., Cambridge. Dept. of Earth, Atmospheric and Planetary Sciences.
EXPERIMENTAL STUDIES OF CRYSTAL-MELT DIFFERENTIATION IN PLANETARY BASALT COMPOSITIONS
T. L. GROVE *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 3 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 20/12

An important process that controls the evolution of magmas on and within planetary bodies is crystal-melt differentiation. Experimental studies of silicate melt solidification were performed on several planetary and terrestrial melt compositions, and experiments on one of these compositions in the microgravity environment of the space station would provide an opportunity to understand the factors that control crystal growth and crystal-melt exchange processes at crystal-melt interfaces during solidification. Experimental requirements are presented. Author

N89-15019*# Massachusetts Inst. of Tech., Cambridge. Dept. of Earth, Atmospheric and Planetary Sciences.
KINETICS OF MINERAL CONDENSATION IN THE SOLAR NEBULA Abstract Only
T. L. GROVE *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 2 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 03/2

A natural extension of the type of gas-mineral-melt condensation experiments is to study the gas-mineral-melt reaction process by controlling the reaction times of appropriate gas compositions with silicate materials. In a condensing and vaporizing gas-solid system, important processes that could influence the composition of and speciation in the gas phase are the kinetics of vaporization of components from silicate crystals and melts. The high vacuum attainable in the space station would provide an environment for studying these processes at gas pressures much lower than those obtainable in experimental devices operated at terrestrial conditions in which the gas phase and mineral or melt would be allowed to come to exchange equilibrium. Further experiments would be performed at variable gas flow rates to simulate disequilibrium vapor fractionation. In this type of experiment it is desirable to analyze directly the species in the gas phase in equilibrium with the condensed silicate material. This analytical method would provide a direct determination of the species present in the gas phase. Currently, the notion of gas speciation is based on calculations from thermodynamic data. The proposed experiments require similar furnace designs and use similar experimental starting compositions, pressures, and temperatures as those described by Mysen. Author

N89-15046*# Geological Survey, Flagstaff, AZ.
MAPPING EXPERIMENT WITH SPACE STATION Abstract Only
SHERMAN S. C. WU *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 2 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 08/2

Mapping the earth from space stations can be approached in two areas. One is to collect gravity data for defining a new topographic datum using the earth's gravitational field in terms of spherical harmonics. The other, which should be considered as a very significant contribution of the Space Station, is to search and explore techniques of mapping the earth's topography using either optical or radar images with or without references to ground control points. Geodetic position of ground control points can be predetermined by the Global Positioning System (GPS) for the mapping experiment with the Space Station. It is proposed to establish four ground control points in North America or Africa (including the Sahara Desert). If this experiment should be successfully accomplished, it may also be applied to the defense charting service. Author

N89-15162*# Ball Corp., Boulder, CO. Space Systems Div.
ELECTRODYNAMIC TETHER SYSTEM STUDY: EXTENDED STUDY Final Report
Sep. 1988 52 p
(Contract NAS9-17666)
(NASA-CR-172115; NAS 1.26:172115) Avail: NTIS HC A04/MF A01 CSCL 22/2

This document is the final report of a study performed by Ball Space Systems Division (BSSD) for the NASA Johnson Space Center under an extension to contract NAS9-17666. The tasks for the extended study were as follows: (1) Define an interface between the Electrodynamic Tether System (ETS) and the Space Station (SS); (2) Identify growth paths for the 100 kW ETS defined in the original study to a 200 kW level of performance; (3) Quantify orbit perturbations caused by cyclic day/night operations of a Plasma Motor/Generator (PMG) on the SS and explore methods of minimizing these effects; (4) Define the analyses, precursor technology, ground tests, and precursor demonstrations leading up to a demonstration mission for an electrodynamic tether system that would be capable of producing maneuvering thrust levels of 25 newtons; and (5) Propose a development schedule for the demonstration mission and preliminary cost estimates. Author

N89-15371*# California Univ., San Diego. Center for Astrophysics and Space Sciences.
SCIENTIFIC TRADEOFFS IN PINHOLE/OCCULTER FACILITY ACCOMMODATION Final Report
HUGH S. HUDSON 16 Dec. 1988 24 p
(Contract NAG8-742)
(NASA-CR-184576; NAS 1.26:184576; SP-88-39) Avail: NTIS HC A03/MF A01 CSCL 14/2

The Pinhole/Occulter Facility (P/OF) consists of state-of-the-art instruments for the study of particle acceleration in the solar corona, and uses a large structure to obtain very high angular resolution. P/OF has been studied in the past as an attached payload for the Space Shuttle, and has been the subject of study by a NASA Science Working Group (P/OFSWG). Appendix A lists various technical studies and reports carried out under the auspices of P/OFSWG and the Program Development Office of NASA Marshall Space Flight Center. Under the rationalization of NASA flight opportunities following the Challenger disaster, and the beginning of the Space Station Freedom program, the sortie-mode deployment of P/OF seemed less efficient and desirable. Thus, NASA decided to reconsider P/OF for deployment on the Space Station Freedom. The technical studies for this deployment continue at the present and will evolve as our knowledge of Space Station architecture and capabilities increase. MSFC contracted with Teledyne Brown Engineering for these technical studies. Author

N89-15517*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
SPACELAB 3 FLIGHT EXPERIMENT NO. 3AFT23: AUTOGENIC-FEEDBACK TRAINING AS A PREVENTIVE METHOD FOR SPACE ADAPTATION SYNDROME
PATRICIA S. COWINGS, WILLIAM B. TOSCANO, JOE KAMIYA, NEAL E. MILLER (Yale Univ., New Haven, CT.), and JOSEPH C. SHARP Oct. 1988 115 p
(NASA-TM-89412; A-87034; NAS 1.15:89412) Avail: NTIS HC A06/MF A01 CSCL 06/19

Space adaptation syndrome is a motion sickness-like disorder which affects up to 50 percent of all people exposed to microgravity in space. This experiment tested a physiological conditioning procedure (Autogenic-Feedback Training, AFT) as an alternative to pharmacological management. Four astronauts participated as subjects in this experiment. Crewmembers A and B served as treatment subjects. Both received preflight training for control of heart rate, respiration rate, peripheral blood volume, and skin conductance. Crewmembers C and D served as controls (i.e., did not receive training). Crewmember A showed reliable control of his own physiological responses, and a significant increase in motion sickness tolerance after training. Crewmember B, however, demonstrated much less control and only a moderate increase in motion sickness tolerance was observed after training. The inflight symptom reports and physiological data recordings revealed that Crewmember A did not experience any severe symptom episodes during the mission, while Crewmember B reported one severe symptom episode. Both control group subjects, C and D (who took antimotion sickness medication), reported multiple symptom episodes on mission day 0. Both inflight data and crew reports indicate that AFT may be an effective countermeasure. Additional data must be obtained inflight (a total of eight treatment and eight control subjects) before final evaluation of this treatment can be made. Author

N89-15797*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
INFRARED MONITORING OF THE SPACE STATION ENVIRONMENT
THEODOR KOSTIUK, DONALD E. JENNINGS, and MICHAEL J. MUMMA *In* NASA, Marshall Space Flight Center, Space Station Induced Monitoring p 39-46 Nov. 1988
Avail: NTIS HC A05/MF A01 CSCL 22/2

The measurement and monitoring of infrared emission in the environment of the Space Station has a twofold importance - for the study of the phenomena itself and as an aid in planning and interpreting Station based infrared experiments. Spectral measurements of the infrared component of the spacecraft glow will, along with measurements in other spectral regions, provide data necessary to fully understand and model the physical and chemical processes producing these emissions. The monitoring of

the intensity of these emissions will provide background limits for Space Station based infrared experiments and permit the determination of optimum instrument placement and pointing direction. Continuous monitoring of temporal changes in the background radiation (glow) will also permit better interpretation of Station-based infrared earth sensing and astronomical observations. The primary processes producing infrared emissions in the Space Station environment are: (1) Gas phase excitations of Station generated molecules (e.g., CO2, H2O, organics...) by collisions with the ambient flux of mainly O and N2. Molecular excitations and generation of new species by collisions of ambient molecules with Station surfaces. They provide a list of resulting species, transition energies, excitation cross sections and relevant time constants. The modeled spectrum of the excited species occurs primarily at wavelengths shorter than 8 micrometer. Emissions at longer wavelengths may become important during rocket firing or in the presence of dust. Author

N89-19329# Technische Univ., Berlin (Germany, F.R.). Inst. fuer Luft- und Raumfahrt.
MODEL OF A GEOSTATIONARY REGIONAL TRANSPORTATION COMPANY (GRET): FLEET COMPOSITION AND FACILITY LAYOUT
U. WIRT, S. AL-KENANY, B. CANPOLAT, D. DALLMANN, A. ECKERT, KLAUS HEINEMANN, R. KLEESSEN, H. W. RENN, R. SCHMUDLACH, and CAREL STUURMAN 1 Aug. 1988 50 p
(ILR-MITT-207; ETN-89-93979) Avail: NTIS HC A03/MF A01

A design and layout study of a commercial, geostationary regional transportation company and related fleet of service vehicles, part of a project for modeling the operation of an infrastructure in geostationary orbit, is summarized. Considering potential customers, orbital environmental conditions and operational procedures, facility and fleet elements were characterized and defined. Based on the configuration of near-future space stations, the hardware was selected and two families of transport vehicles as well as a cluster of servicing vehicles were designed. ESA

N89-19330# Technische Univ., Berlin (Germany, F.R.). Inst. fuer Luft- und Raumfahrt.
PRELIMINARY COST MODEL FOR A COMMERCIAL GEOSTATIONARY TRANSPORTATION COMPANY (GRET)
H. H. KOELLE, Z. MATIJEVIC, J. CZARNITZKI, KLAUS HEINEMANN, HAKAN KAYAL, CLAUDIA LOTZE, JUERGEN MAYER, HATTO W. RENN, FRANK SCHNEIDER, CAREL STUURMAN et al. 1 Aug. 1988 34 p
(ILR-MITT-208; ETN-89-93980) Avail: NTIS HC A03/MF A01

The cost of one element of the geostationary orbital infrastructure was estimated. This element is a commercial transportation company to serve all other elements of the GEO infrastructure, offering passenger and cargo transportation within the local GEO regime. The estimates result in a figure of 30 billion dollars for the acquisition phase and annual expenses between 3 and 4 billion during the operational phase. Calculations show that it takes 20 yr before a positive cash flow can be expected and up to 40 yr before a (big) profit can be made. ESA

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OPERATIONS SUPPORT

Includes descriptions of models, analyses and trade studies of maneuvers, performance, Logistics support, and EVA and/or IVA servicing requirements of systems such as the OMV and OTV, and experiments.

A89-12069*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
AUTOMATED ORBITAL RENDEZVOUS CONSIDERATIONS
ROBERT N. LEA (NASA, Johnson Space Center, Houston, TX) IN: 1988 IEEE International Conference on Robotics and Automation, Philadelphia, PA, Apr. 24-29, 1988, Proceedings. Volume 3. Washington, DC, Computer Society Press, 1988, p. 1871, 1872. refs

The control of the rendezvous vehicle during proximity operations is considered. It is shown how fuzzy sets can be used for autonomous vehicle control to model the human capability of common sense reasoning. Such models are integrated with expert systems and engineering control systems technology to create a system that performs comparably to a manned system. I.E.

A89-14986#
ACHIEVING OPERATIONAL EFFICIENCY WITH THE INTERNATIONAL SPACE STATION
PETER R. KURZHALS and STEPHEN G. PADDOCK (McDonnell Douglas Astronautics Co., Space Station Div., Huntington Beach, CA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 9 p.
(IAF PAPER 88-083)

The evolutionary development of flight operations for the Space Station Manned Base (SSMB) Freedom focuses on station efficiency during assembly, inflight verification, and continuous manned operations. Operations Engineering, the first stage of this evolution, will ensure operational safety and efficiency through a functional analysis that transforms operations requirements into system design drivers to minimize station housekeeping overhead and maximize user support. Operations Preparation, the second stage, will develop products for flight activities, operations integration, and ground support that reduce ground support overhead while maintaining flight safety. Operations Execution, the third and final stage, will implement the plans and procedures for on-orbit missions and ground support. Special emphasis is placed on incorporation of program commonality to minimize operations complexity, on integrated crew training and implementation concepts to assure effective use of crew resources, and on computer-aided processes to streamline operations data management. These efficiency features will enable major reductions in the size of support teams required for station operations and are expected to save billions of dollars over the SSMB lifetime. Author

A89-15854
DOCKING/BERTHING SENSOR USING A LASER DIODE RANGEFINDER, CCD AND VIDEO TRACKER
G. STEPHEN MECHERLE (Hughes Aircraft Co., El Segundo, CA) IN: Acquisition, tracking, and pointing II; Proceedings of the Meeting, Los Angeles, CA, Jan. 14, 15, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 88-95. Research supported by the Hughes Aircraft Co.

A laser docking sensor for STS orbiter satellite retrieval, Space Station rendezvous with the OMV and STS orbiter, and orbiter/lander docking for interplanetary missions is discussed. A laser docking sensor design is presented using a laser diode rangefinder, CCD array with active laser diode illumination and multitarget video tracker. Author

A89-16522*# Booz-Allen and Hamilton, Inc., Arlington, VA.
SPACE STATION ASSEMBLY SEQUENCE PLANNING - AN ENGINEERING AND OPERATIONAL CHALLENGE
JAMES T. KAIDY and WILLIAM G. BASTEDO (Booz-Allen and Hamilton, Inc., Reston, VA) AIAA, Space Programs and Technologies Conference, Houston, TX, June 21-24, 1988. 10 p. refs
(Contract NASW-4300)
(AIAA PAPER 88-3500)

This paper discusses the Space Station assembly sequence planning and development process. It presents the planning methodologies from both historial and current perspectives. It is shown that planning the assembly sequence is a new and unique challenge and its solution requires the simultaneous satisfaction of many diverse variables and constants. The considerations which influence the development of the assembly sequence include launch vehicle integration and lift capabilities, on-orbit assembly

flight operations, vehicle flight dynamics, spacecraft system capabilities and resource availability. Many of these considerations are described in this paper. In addition, the examples presented demonstrate the current process for assembly sequence planning and show many of the complex trade-offs that must be performed. Author

A89-16542#
SPACE STATION - TOWARD STATION OPERABILITY
GREGORY R. BENNETT and STEPHEN G. PADDOCK (McDonnell Douglas Astronautics Co., Saint Louis, MO) Aerospace America (ISSN 0740-722X), vol. 26, Nov. 1988, p. 21, 22, 24.

Systematic operations engineering and the development of an automated operations management system (OMS) are presented as key elements of NASA's Space Station design development effort. The OMS software, which will take care of routine Space Station operations, encompasses on-board and ground-based components. Flight profiles, resource-utilization plans, crew training plans, flight-support operations, flight rules, and crew timelines all inform the OMS data base. O.C.

A89-16544#
SPACE STATION - GETTING MORE OUT OF EVA
FRED ABELES (Grumman Aerospace Corp., Bethpage, NY) Aerospace America (ISSN 0740-722X), vol. 26, Nov. 1988, p. 29, 30.

The NASA Space Station's EVA System will encompass an Extravehicular Mobility Unit (EMU), comprising space suit, life support system, and communications system, and the thruster-powered Manned Maneuvering Unit, mounted on the astronaut's back. An account is presently given of the differences between the Space Shuttle Orbiter and Space Station that have most significantly affected the design of the EMU. O.C.

A89-17859*# NASA Space Station Program Office, Reston, VA.
SPACE STATION FREEDOM OPERATIONS COSTS
ANNE L. ACCOLA and GREGORY J. WILLIAMS (NASA, Space Station Freedom Program Office, Reston, VA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988 7 p.
(IAF PAPER 88-572)

Measures to reduce the operation costs of the Space Station which can be implemented in the design and development stages are discussed. Operational functions are described in the context of an overall operations concept. The provisions for operations cost responsibilities among the partners in the Space Station program are presented. Cost estimating methodologies and the way in which operations costs affect the design and development process are examined. R.B.

A89-18130*# Sterling Software, Palo Alto, CA.
AN EVALUATION OF INTERACTIVE DISPLAYS FOR TRAJECTORY PLANNING AND PROXIMITY OPERATIONS
ADAM R. BRODY (Sterling Software, Inc., Palo Alto, CA), STEPHEN R. ELLIS, ART GRUNWALD, and RICHARD F. HAINES (NASA, Ames Research Center, Moffett Field, CA) IN: AIAA/IEEE Digital Avionics Systems Conference, 8th, San Jose, CA, Oct. 17-20, 1988, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 542-547.
(AIAA PAPER 88-3963)

Rendezvous, docking, and other Space Station proximity operations will be routine in nature in years to come. However, the specific parameters describing each maneuver, such as initial range and position, will vary from mission to mission so a means for depicting and interacting with graphic representations of proposed mission plans is necessary. Orbital operations are inherently non-intuitive due to non-linearities in the equations of motion of orbiting vehicles. Consequently, relative motion between two spacecraft cannot always be easily visualized. For these reasons, real time interactive visual aids and planning tools will be helpful, if not necessary, for future missions both in pre-flight training and on-orbit. Two such displays, Navie and eivaN, are currently available for examination and human factors testing. Since the docking tasks were fundamentally different with each device and because Navie imposed more constraints on the users than eivaN did, the orbital mechanics effects had a more pronounced effect on the Navie results. Author

A89-18168*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
DEVELOPMENT OF A SPACE STATION OPERATIONS MANAGEMENT SYSTEM
A. E. BRANDLI (NASA, Johnson Space Center, Houston, TX) and W. T. MCCANDLESS (Lockheed Engineering and Sciences Co., Houston, TX) IN: AIAA/IEEE Digital Avionics Systems Conference, 8th, San Jose, CA, Oct. 17-20, 1988, Technical Papers. Part 2. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 775-779.
(AIAA PAPER 88-3973)

To enhance the productivity of operations aboard the Space Station, a means must be provided to augment, and frequently to supplant, human effort in support of mission operations and management, both on the ground and onboard. The Operations Management System (OMS), under development at the Johnson Space Center, is one such means. OMS comprises the tools and procedures to facilitate automation of station monitoring, control, and mission planning tasks. OMS mechanizes, and hence rationalizes, execution of tasks traditionally performed by mission planners, the mission control center team, onboard System Management software, and the flight crew. Author

A89-18309*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
OPSMODEL, AN OR-ORBIT OPERATIONS SIMULATION MODELING TOOL FOR SPACE STATION
WILLIAM T. DAVIS and ROBERT L. WRIGHT (NASA, Langley Research Center, Hampton, VA) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 10 p. refs
(AIAA PAPER 88-4732)

The 'OPSMODEL' operations-analysis and planning tool simulates on-orbit crew operations for the NASA Space Station, furnishing a quantitative measure of the effectiveness of crew activities in various alternative Station configurations while supporting engineering and cost analyses. OPSMODEL is entirely data-driven; the top-down modeling structure of the software allows the user to control both the content and the complexity level of model definition during data base population. Illustrative simulation samples are given. O.C.

A89-18312*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
FUTURE CIVIL SPACE PROGRAM LOGISTICS
JAMES W. STEINCAMP (NASA, Marshall Space Flight Center, Huntsville, AL) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 8 p.
(AIAA PAPER 88-4735)

The NASA Shuttle-C unmanned launch vehicle and the Shuttle/Space Station-based Orbital Maneuver Vehicle will be used in support of NASA Space Station assembly and logistics operations, as well as for the orbital servicing of the Hubble Space Telescope (1989), the Advanced X-ray Astrophysical Facility (1996), and the Space Infrared Telescope Facility (1998). Accounts are presently given of these observatories' configurations, capabilities, and mission scenarios, as well as of the Shuttle-C-based Space Station assembly sequence. O.C.

A89-18315*# National Aeronautics and Space Administration, Washington, DC.
SPACE STATION RESUPPLY USING EXPENDABLE LAUNCH VEHICLES
ROBERT KEMPINSKI (Grumman Corp., Grumman Space Station Program Support Div., Reston, VA) and DONALD TEAGUE (NASA, Washington, DC) IN: AIAA/SOLE Space Logistics Symposium,

2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 11 p. refs
(AIAA PAPER 88-4738)

The usefulness of the use of ELVs, including those of other nations, to supplement the Space Shuttle in resupplying the NASA Space Station is evaluated. Two reference ELV resupply missions are analyzed: the first uses a space-based transfer vehicle, such as the Orbital Maneuvering Vehicle, for berthing and deberthing; the second relies on an active transfer vehicle to deliver the logistics element directly to the Space Station. An account is given of the program-management implications of the proposed use of ELVs. O.C.

A89-18316#
MAINTENANCE AND REPAIR ON SPACELAB
BYRON LICHTENBERG (Payload Systems, Inc., Wellesley, MA) and WILLIAM C. LEWIS (Grand Valley State University, Allendale; Research and Technology Institute, Grand Rapids, MI) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 4 p.
(AIAA PAPER 88-4739)

An effort is made to correct the paucity of basic and systematic consideration concerning the choice of spacecraft equipment that ought to be repaired, modified, or maintained in orbit; the choice of tools and astronaut training methods and goals hace also been neglected. The present discussion of the nature of maintenance and repair applies its conclusions to the various equipment classifications encompassed by Spacelab, in order to arrive at a systematic and rigorous first-principles approach. User, intermediate, and depot maintenance-categories are identified. O.C.

A89-18321*# National Aeronautics and Space Administration. John F. Kennedy Space Center, Cocoa Beach, FL.
SPACE STATION MAINTENANCE CONCEPT STUDY
ERIC E. NELSON (NASA, Kennedy Space Center; McDonnell Douglas Astronautics Co., Cocoa Beach, FL) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 3 p.
(AIAA PAPER 88-4745)

The relationships among NASA Space Station operational constraints and logistical requirements are presently investigated. The concepts studied locate organizational, intermediate, and depot maintenance at the Space Station, at the Kennedy Space Center (KSC), and at a depot remote from the KSC. Measures of reliability, maintainability, and availability were selected; a life-cycle study was then conducted to ascertain the optimum Space Station system maintenance concept. The results obtained indicate that orbital replacement unit MTBFs should not be less than 36,000 hours. O.C.

A89-18322#
ON-ORBIT MAINTENANCE - A PERSPECTIVE
WALBERT G. MCCOY (U.S. Space Command, Peterson AFB, CO) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 4 p.
(AIAA PAPER 88-4746)

An evaluation is made of the requirements and events leading to the establishment of a space-based assembly/maintenance/servicing capability. The aggregate analysis that has been conducted, which treats the space logistics infrastructure as one consolidated group of requirements in order to define an integrated space-based system, is expected to yield cost-savings in both the development and operation of such programs as SDI satellites and the NASA Hubble Space Telescope through the identification of common requirements and potential supportability overlaps. O.C.

A89-18323*# CACI, Inc., Arlington, VA.
THE SUPPORT CONSTRAINTS FOR ORBITAL SYSTEMS - HOW TO MEASURE THE R&M EFFECTS
CARL S. WEISMAN (CACI International, Inc., Arlington, VA) and RICHARD E. STORM (NASA, Space Station Freedom Program Office, Reston, VA) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 4 p.
(AIAA PAPER 88-4748)

The loss of the space shuttle Challenger cast doubt on many issues of Space Station support. Modeling alternatives runs into theoretical difficulties. This paper reports on a modeling approach that accounts for a fixed resupply cycle in reliability estimates for a single orbital system. The emphasis in the single-system model is on ground-based support, rather than on orbital activities and constraints. The paper also provides a scheme in outline for a multi-system model that similarly reflects Space Station restorability concepts, but accounts for cross-system competition for on-orbit resources and access to launch vehicle space. Author

A89-18326#
ROGER B. CHAFFEE SPACE OPERATIONS LOGISTICS ENGINEERING RESEARCH CENTER
BRUCE A. CHUBB (Research and Technology Institute, Grand Rapids, MI) and WILLIAM C. LEWIS (Grand Valley State University, Allendale, MI) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 6 p. refs.
(AIAA PAPER 88-4751)

A consortium of university research interests has conceived a NASA organization, to be designated the 'Roger B. Chaffee Space Operations Logistics Engineering Research Center', whose initial concerns will extend to the analysis of NASA Space Station ready-spares inventory, ground repair and reconditioning systems, automated inventory and configuration management, on-orbit component-level repair, and packaging. The results of Logistics Center studies would aid equipment suppliers in the optimization of logistics requirements and in the improvement of long term space operations' cost-effectiveness. O.C.

A89-18327#
APPLICATION OF QUEUING THEORY TO ON-ORBIT LOGISTICS
DAVID P. MARTIN, II (Science Applications International Corp., Colorado Springs, CO) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 6 p. refs
(AIAA PAPER 88-4752)

Models to analyze on-orbit maintenance and support of space vehicles have looked at only a portion of the overall problem of transportation, servicing and ground support of space-based assets. This has caused problems in understanding the complexity of on-orbit support and hindered studies into the cost-effectiveness of the benefits of on-orbit support versus current support methods. Using a technique previously applied to an analysis of the Space Shuttle, on-orbit modeling can be performed from a systems perspective with available queuing models to help answer critical questions on resource utilization, success rate, and time expenditure required to perform on-orbit logistics support. Benefits from greater flexibility and expandability are achieved using the queuing theory technique. Author

A89-18328*# National Aeronautics and Space Administration. John F. Kennedy Space Center, Cocoa Beach, FL.
A SIMULATION PROGRAM FOR THE ANALYSIS OF ON-ORBIT SPACE STATION MAINTENANCE AND LOGISTICS OPERATIONS
KELLY L. FURLONG and EDMUND T. DEJULIO (NASA, Kennedy Space Center; Boeing Co., Cocoa Beach, FL) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988,

Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 9 p. refs
(AIAA PAPER 88-4753)

This paper describes the analysis approach adopted by NASA's Space Station Maintenance Planning and Analysis (MPA) Study and focuses on the development and use of a simulation program called Simulation of Manned Space System Logistics Support (SIMSYLS) for modeling the Space Station operations environment. The basic assumptions and groundrules used in the development of SIMSYLS are presented, including its capabilities, limitations and samples of analyses performed. Finally, a proposed simulation outgrowth entitled Space Applications System Simulation (SASS) is described. SIMSYLS will constitute the foundation for SASS which will provide a full system operational RAM analysis tool for Space Station and its logistics support environment. Author

A89-19913*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
ON-ORBIT DAMAGE ASSESSMENT FOR LARGE SPACE STRUCTURES
JAY-CHUNG CHEN and JOHN A. GARBA (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) (Structures, Structural Dynamics and Materials Cenference, 28th, Monterey, CA, Apr. 6-8, 1987, Technical Papers. Part 1, p. 714-721) AIAA Journal (ISSN 0001-1452), vol. 26, Sept. 1988, p. 1119-1126. Previously cited in issue 14, p. 2169, Accession no. A87-33634. refs

A89-19946#
DEVELOPMENT OF EQUIPMENT EXCHANGE UNIT FOR JAPANESE EXPERIMENT MODULE OF SPACE STATION
Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 28, July 1988, p. 213-217. In Japanese, with abstract in English. Research supported by the National Space Development Agency of Japan.

This paper describes the research and development of the equipment exchange unit (EEU) to be attached to the exposed facility (EF) composing Japanese Experiment Module (JEM) of the Space Station to be launched in the latter half of the 1990s. The EEU is capable of attaching and detaching automatically an experimental apparatus transferred by the remote manipulator system aboard the JEM and at the same time connecting utilities such as electric power and control circuits, heat control fluids, etc. The EEU is indispensable for the servicing of the EF and future space equipment which defies the Extravehicular Activities. IHI initiated its research and development in 1983 which is now vigorously pursued under the EEU research and development project started under the sponsorship of NASDA. Author

A89-20836* TRW, Inc., Redondo Beach, CA.
AUTOMATED LOW-THRUST GUIDANCE FOR THE ORBITAL MANEUVERING VEHICLE
RICHARD E. ROSE, HARRY SCHMEICHEL, CHARLES P. SHORTWELL, and RONALD A. WERNER (TRW, Inc., TRW Space and Defense Sector, Redondo Beach, CA) IN: Guidance and control 1988; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 30-Feb. 3, 1988. San Diego, CA, Univelt, Inc., 1988, p. 109-129.
(Contract NAS8-36800)
(AAS PAPER 88-007)

This paper describes the highly autonomous OMV Guidance Navigation and Control system. Emphasis is placed on a key feature of the design, the low thrust guidance algorithm. The two guidance modes, orbit change guidance and rendezvous guidance, are discussed in detail. It is shown how OMV will automatically transfer from its initial orbit to an arbitrary target orbit and reach a specified rendezvous position relative to the target vehicle. Author

A89-21804* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
AUTOMATED SPACE VEHICLE CONTROL FOR RENDEZVOUS PROXIMITY OPERATIONS
ROBERT N. LEA (NASA, Johnson Space Center, Houston, TX) (NASA, 1988 Goddard Conference on Space Applications of Artificial Intelligence, Greenbelt, MD, May 24, 1988) Telematics and Informatics (ISSN 0736-5853), vol. 5, no. 3, 1988, p. 179-185. Previously announced in STAR as N88-30335. refs

Rendezvous during the unmanned space exploration missions, such as a Mars Rover/Sample Return will require a completely automatic system from liftoff to docking. A conceptual design of an automated rendezvous, proximity operations, and docking system is being implemented and validated at the Johnson Space Center (JSC). The emphasis is on the progress of the development and testing of a prototype system for control of the rendezvous vehicle during proximity operations that is currently being developed at JSC. Fuzzy sets are used to model the human capability of common sense reasoning in decision-making tasks and such models are integrated with the expert systems and engineering control system technology to create a system that performs comparably to a manned system. Author

A89-25089*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE REUSABLE REENTRY SATELLITE - A MISSION AND SYSTEM DESCRIPTION AND OPERATIONAL CONCEPT
BYRON L. SWENSON, ALFRED C. MASCY, and ROBERT W. JACKSON (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 20 p. refs
(AIAA PAPER 89-0101)

A significant need exists for a system which will provide the life science experimenter with relatively frequent and inexpensive access to the space environment. To fulfill this need, a project and spacecraft system described as the Reusable Reentry Satellite (RRS) or LifeSat has been proposed by NASA. The RRS provides a relatively inexpensive method of access to space for extended periods of time and eventual intact recovery of the experiments on the earth's surface. The payload support requirements, flight operations concept are reviewed and the mission and system of the RRS are described in detail. C.D.

A89-25330*# NASA Space Station Program Office, Reston, VA.
SPACE STATION OPERATIONS MANAGEMENT
KATHLEEN V. CANNON (NASA, Space Station Freedom Program Office, Reston, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0393)

Space Station Freedom operations management concepts must be responsive to the unique challenges presented by the permanently manned international laboratory. Space Station Freedom will be assembled over a three year period where the operational environment will change as significant capability plateaus are reached. First Element Launch, Man-Tended Capability, and Permanent Manned Capability, represent milestones in operational capability that is increasing toward mature operations capability. Operations management concepts are being developed to accomodate the varying operational capabilities during assembly, as well as the mature operational environment. This paper describes operations management concepts designed to accomodate the uniqueness of Space Station Freedoom, utilizing tools and processes that seek to control operations costs. Author

A89-25333*# Ocean Systems Engineering, Inc., Falls Church, VA.
OPPORTUNITIES FOR SPACE STATION ASSEMBLY OPERATIONS DURING CREW ABSENCE
JOSEPH C. PARRISH (Ocean Systems Engineering, Inc., Falls Church, VA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. Research supported by Ocean Systems Engineering, Inc. refs
(Contract NASW-4300)
(AIAA PAPER 89-0398)

Prior to Permanently Manned Capability (to be achieved approximately 21 months after the First Element Launch), the Space Station will be manned for less than 10 percent of its total

staytime on orbit. The most intensive and critical Station assembly operations will occur during these early flights. Some robotic resources may be available to perform assembly operations while the Station crew is absent; however, the use of robotic devices for assembly operations during unmanned phases has not yet been adopted by the Space Station program. This paper studies the relevant aspects of teleoperated and autonomous assembly activities, and presents candidate assembly operations that could be performed during crew absence. From this analysis, the potential benefits of remote control of robotic resources can be weighed against any associated increase in cost and complexity that would accompany implementation of this capability. Author

A89-25334*# Booz-Allen and Hamilton, Inc., Bethesda, MD.
AUTOMATING SPACE STATION OPERATIONS PLANNING
KATHLEEN A. ZIEMER (Booz, Allen and Hamilton, Inc., Bethesda, MD) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p. refs
(Contract NASW-4300)
(AIAA PAPER 89-0399)

The development and implementation of the operations planning processes for the Space Station are discussed. A three level planning process, consisting of strategic, tactical, and execution level planning, is being developed. The integration of the planning procedures into a tactical planning system is examined and the planning phases are illustrated. R.B.

A89-25466*# National Aeronautics and Space Administration. John F. Kennedy Space Center, Cocoa Beach, FL.
LAUNCH SITE PAYLOAD TEST CONFIGURATIONS FOR SPACE SHUTTLE SCIENTIFIC PAYLOADS
ROELOF L. SCHUILING and MAYNETTE S. MAYER (NASA, Kennedy Space Center, Cocoa Beach, FL) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 6 p.
(AIAA PAPER 89-0581)

This paper provides an overview of the test configurations which are utilized in prelaunch testing at the John F. Kennedy Space Center (KSC) for those scientific payloads which are flown in the National Space Transportation System (NSTS) Space Shuttle. A generalized view of the payload prelaunch processing is provided and the major types of payload configurations are described. The majority of the prelaunch test activity involves the verification of experiment functions, compatibility of experiment-to-carrier interfaces and payload-to-orbiter interfaces. The Shuttle's avionics system is presented as it relates to payloads. The testing of Spacelab experiments and the experiment-to-Spacelab compatibility verification is described as is the test activity for partial payloads and their experiments. Test operations which involve simulated orbiter interface verification and actual payload-to-orbiter testing are discussed. An overview of the Space Station payload processing concept is presented. Author

A89-25469#
OMV MISSION OPERATIONS
JAMES SARINA (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 5 p.
(AIAA PAPER 89-0587)

The OMV, a reusable remotely controlled free-flying space vehicle, is capable of performing a wide range of services to orbiting spacecraft. The Design, Development, Test, and Evaluation mission will demonstrate the OMV's capabilities and serve as a precursor for the operational program which will encompass Space Station and space-based mode operations in addition to orbiter-based operations. OMV ground operations include real-time, man-in-the-loop, and remote teleoperations. K.K.

A89-25625*# Computer Technology Associates, Inc., Lanham, MD.
MIL-C-38999 ELECTRICAL CONNECTOR APPLICABILITY TESTS FOR ON-ORBIT EVA SATELLITE SERVICING
THOMAS J. GRIFFIN (Computer Technology Associates, Inc., Lanham, MD) and RUTHAN LEWIS (NASA, Goddard Space Flight Center, Greenbelt, MD) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(AIAA PAPER 89-0860)

MIL-C-38999 electrical connectors were tested for their applicability to the on-orbit EVA satellite servicing environment. The investigation provided a methodical approach to the evaluation of the human-machine interface of these connectors. The physical characteristics of thirty-five MIL-C-38999 connectors were tested in two simulated space environments, the NASA Johnson Space Center Weightless Environment Training Facility and an evacuated glovebox which incorporated the Extravehicular Maneuvering Unit series 3000 gloves. Physical characteristics of the connectors were documented, including operating torque and work profiles. STS crewmembers tested a select group of connectors in two WETF test and subjectively ranked the G&H PMM Wing-Tab connectors as most applicable to the on-orbit servicing environment. WETF performance times indicated that the G&H PMM Wing-Tab connector had the fastest operating time. The evacuated glovebox participants ranked the G&H 64600 Wing-Tab and the G&H PMM Wing-Tab connectors as those most applicable to the on-orbit servicing environment. During the evacuated glovebox tests, the G&H 64600 Wing-Tab connector had the fastest operating time. Author

A89-26382#
THE TECHNIQUES OF MANNED ON-ORBIT ASSEMBLY
LEON B. WEAVER (Weaver Enterprises, Aptos, CA) IN: Commercial opportunities in space; Symposium, Taipei, Republic of China, Apr. 19-24, 1987, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 85-95.

The activities required to design, test, place, and activate large space systems are discussed, focusing on the manned on-orbit assembly of space systems. The development of the assembly process, the selection of a specific design solution, and the use of EVA simulations and analysis are considered. The requirements for valid manned EVA simulations are outlined. The major simulation mediums are examined, including one-G, neutral buoyancy, zero-G, and reduced-G atmospheric flight. R.B.

A89-26383#
ON THE ORBITER BASED CONSTRUCTION OF THE SPACE STATION AND ASSOCIATED DYNAMICS
V. J. MODI and A. M. IBRAHIM (British Columbia, University, Vancouver, Canada) IN: Commercial opportunities in space; Symposium, Taipei, Republic of China, Apr. 19-24, 1987, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 96-113. refs
(Contract NSERC-67-1547)

The interactions between deployment, attitude dynamics, and flexural rigidity for two configurations representing beam and tether type deployment are examined using a relatively general formulation procedure. The results suggest that the flexibility, deployment velocity, initial conditions, and appendage orientation have substantial influence on the system response. It is shown that the system can become unstable under critical combinations of parameters. It is suggested that the research is relevant to the design of control systems for communications satellites, orbiter-based experiments, and the evolutionary transient and postconstruction operational phases of the Space Station. R.B.

A89-27601
INTERNATIONAL CONFERENCE ON INDUSTRIAL AND ENGINEERING APPLICATIONS OF ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS, 1ST, UNIVERSITY OF TENNESSEE, TULLAHOMA, JUNE 1-3, 1988, PROCEEDINGS. VOLUMES 1 & 2
Conference sponsored by the University of Tennessee. Tullahoma, TN, University of Tennessee, 1988, p. Vol. 1, 654 p.; vol. 2, 566 p. For individual items see A89-27602 to A89-27630.

The conference presents papers on expert systems for fault diagnosis, expert system technology, expert systems applications, expert systems for design, and expert systems for process control.

Consideration is given to pattern-based fault diagnosis using neural networks, diagnosing multiple faults using knowledge about malfunctioning behavior, approximate spatial reasoning, and integrating causal reasoning at different levels of abstraction. Other topics include uncertainty management in intelligent design aiding systems, a representational language for qualitative process control, and a neural control element in a control systems application. K.K.

A89-27832
OMV - AN ORBITAL LIFE SUPPORT TEST BED
WILLIAM L. SMITH and KENNETH H. ROUBKE (TRW, Inc., Federal Systems Div., Redondo Beach, CA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 10 p.
(SAE PAPER 881030)

This paper describes a new application of the Orbital Maneuvering Vehicle (OMV) systems' capability as an orbital test bed to support life support experiments, as a deployer/retriever of life support experimental Lightsats, or as a servicer of life support experiments for platforms or spacecraft. As an experiment carrier or support vehicle, the OMV can remove the experiment or engineering test bed from the National Space Transportation System or Space Station environmental influences. Both the primary OMV capability to support short-term experiments as well as intermediate-duration evaluations of the life support system are explored. S.A.V.

A89-27860* United Technologies Corp., Windsor Locks, CT.
A NONVENTING COOLING SYSTEM FOR SPACE ENVIRONMENT EXTRAVEHICULAR ACTIVITY, USING RADIATION AND REGENERABLE THERMAL STORAGE
STEPHEN A. BAYES (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT), LUIS A. TREVINO (NASA, Johnson Space Center, Houston, TX), and CRAIG E. DINSMORE (Rockwell International Corp., Pittsburgh, PA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 13 p.
(SAE PAPER 881063)

This paper outlines the selection, design, and testing of a prototype nonventing regenerable astronaut cooling system for extravehicular activity space suit applications, for mission durations of four hours or greater. The selected system consists of the following key elements: a radiator assembly which serves as the exterior shell of the portable life support subsystem backpack; a layer of phase change thermal storage material, n-hexadecane paraffin, which acts as a regenerable thermal capacitor; a thermoelectric heat pump; and an automatic temperature control system. The capability for regeneration of thermal storage capacity with and without the aid of electric power is provided. Author

A89-27862* Grumman Aerospace Corp., Bethpage, NY.
DEVELOPMENT OF AN AUTOMATED CHECKOUT, SERVICE AND MAINTENANCE SYSTEM FOR A SPACE STATION EVAS
FRED J. ABELES (Grumman Corp., Space Station Program Support Div., Bethpage, NY), TERRY TRI (NASA, Johnson Space Center, Houston, TX), and ROBERT BLASER (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p.
(SAE PAPER 881065)

The development of a new operational system for the Space Station will minimize the time normally spent on performing on-orbit checkout, servicing, and maintenance of an extravehicular activity system of the Space Station. This system, the Checkout, Servicing, and Maintenance System (COSM), is composed of interactive control software interfacing with software simulations of hardware components. The major elements covered in detail include the controller, the EMU simulator and the regenerative life support system. The operational requirements and interactions of the individual elements as well as the protocols are also discussed. A.A.F.

A89-27885
EVA EQUIPMENT DESIGN - HUMAN ENGINEERING CONSIDERATIONS
H. T. FISHER (Lockheed Missiles and Space Co., Inc., Astronautics Div., Sunnyvale, CA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 9 p.
(SAE PAPER 881090)

The Space Station presents a plethora of human factors engineering opportunities. In particular, design for the space suited EVA crewperson is critical from aspects including: safety, ease of task conduct, timeline reductions, risk elimination, and productivity enhancement. This paper will address the human factors engineering effort undertaken to aid in the early-on design of the Space Station structure, with particular emphasis on structural assembly operations. Author

A89-28216* Grumman Aerospace Corp., Bethpage, NY.
PLANNING FOR ORBITAL REPAIRS TO THE SPACE STATION AND EQUIPMENT
HARRY S. HABER (Grumman Corp., Integrated Logistics Support Dept., Bethpage, NY) and ALBERTA QUINN (NASA, Marshall Space Flight Center, Huntsville, AL) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 12 p. refs
(SAE PAPER 881446)

This paper summarizes an extensive study that was performed to establish a baseline for tools, materials, and repair techniques that will be needed for an astronaut to repair structures in an orbital environment, with a view towards future on-orbit repairs to the Space Station. The study program confirmed the premise that repairs must and can be made by astronauts while in an orbital environment. Scenarios for both welding repair and composite repair techniques are presented, along with a discussion of human factors considerations. A Space Station maintenance work station module is described, followed by a discussion of the Neutral Buoyancy Simulator test facility used to evaluate crew work performance in zero g conditions. S.A.V.

A89-28231* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SPACE STATION FREEDOM OPERATIONS PLANNING
KEVIN J. SMITH (NASA, Johnson Space Center; Barrios Technology, Inc., Houston, TX) SAE, Aerospace Technology Conference and Exposition, Anaheim, CA, Oct. 3-6, 1988. 10 p.
(SAE PAPER 881493)

This paper addresses the development of new planning methodologies which will evolve to serve the Space Station Freedom program; these planning processes will focus on the complex task of effectively managing the resources provided by the Space Station Freedom and will be made available to the diverse international community of space station users in support of their ongoing investigative activities. Author

A89-28272
SPACE LOGISTICS - SWITZERLAND ACCEPTS THE CHALLENGE [WELTRAUMLOGISTIK - AUCH DIE SCHWEIZ STELLT SICH DER HERAUSFORDERUNG]
JOSEF KAPOUN (Logistics Consulting, Fribourg, Switzerland) Astronautik (ISSN 0004-6221), vol. 25, Oct.-Dec. 1988, p. 111, 112. In German.

The Swiss ESA role in providing logistics for space flights is discussed. The nature of space logistics is summarized, and requirements for improving space logistics are outlined. The application of logistics to individual aspects of space flight are described, including launch and landing, rescue, space transport, payload, and manned activities. C.D.

A89-29406
MULTI-ROLE CAPSULE OPERATIONS
RUSSELL J. HANNIGAN (British Aerospace, PLC, Space and Communications Div., Stevenage, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 42, Feb. 1989, p. 82-87.

The Multi-Role Capsule concept offers reliable, low cost and safe manned access to and from space for near future European low earth orbit activities. The operational aspects of performing a typical crew delivery to the Man-Tended Free-Flyer and International Space Station are described in outline. In addition, possible emergency contingency situations which could emerge during all phases of operation are also discussed, demonstrating the flexibility of the MRC system design. Author

A89-29654#
PATCHING UP THE SPACE STATION
MARTIN N. GIBBINS and PAUL H. STERN (Boeing Aerospace, Seattle, WA) Aerospace America (ISSN 0740-722X), vol. 27, March 1989, p. 32, 33.

The emergency procedures for the repair of punctures in the Space Station pressure-wall seal are outlined. Several repair patch designs are described. Special repair tools with tether attachment ring and Velcro-lined handles are discussed. Also, the processes for cleaning and marking the repaired puncture are considered. Preliminary results from laboratory and simulation tests of these procedures are presented. R.B.

A89-31467#
MISSION FUNCTION CONTROL FOR DEPLOYMENT AND RETRIEVAL OF A SUBSATELLITE
HIRONORI FUJII and SHINTARO ISHIJIMA (Tokyo Metropolitan Institute of Technology, Japan) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090), vol. 12, Mar.-Apr. 1989, p. 243-247. Previously cited in issue 22, p. 3550, Accession no. A87-50447. refs

A89-31608
THE HELMET-MOUNTED DISPLAY AS A TOOL TO INCREASE PRODUCTIVITY DURING SPACE STATION EXTRAVEHICULAR ACTIVITY
C. K. SHEPHERD, JR. (Lockheed Engineering and Sciences Co., Houston, TX) IN: Human Factors Society, Annual Meeting, 32nd, Anaheim, CA, Oct. 24-28, 1988, Proceedings. Volume 1. Santa Monica, CA, Human Factors Society, 1988, p. 40-43. refs

The human factors issues related to the helmet-mounted displays (HMDs) designed for the information system of the Space Station Extravehicular Mobility Unit are discussed. The amount and type of information that must be presented by the HMD and the physical capabilities of a suited astronaut are examined. A voice-interactive rapid prototyping system used to simulate and evaluate the use of the HMD in EVA is described. It is concluded that the HMD is safe for use in Space Station EVA. R.B.

A89-31760
ABOVE THE PLANET - SALYUT EVA OPERATIONS
NEVILLE KIDGER Spaceflight (ISSN 0038-6340), vol. 31, March 1989, p. 102-105.

EVA operations on the Salyut station between August 1979 and November 1983 are reviewed. The first unscheduled EVA on the station, the removal of a jammed radio telescope dish, is discussed. Other operations include the collection of samples of organic compounds and metals as part of external experiments and the installation of solar panels. R.B.

A89-32126
THE GAGARIN SCIENTIFIC LECTURES ON ASTRONAUTICS AND AVIATION 1987 [GAGARINSKIE NAUCHNYE CHTENIIA PO KOSMONAVTIKE I AVIATSII 1987 G.]
A. IU. ISHLINSKII, ED. Moscow, Izdatel'stvo Nauka, 1988, 168 p. In Russian. No individual items are abstracted in this volume.

Reports given at the 17th Gagarin Lectures (1987) and the 16th Lectures (1986) are presented. Works are presented on problems in flight mechanics, gas dynamics, and modern techniques for the automated design of flight vehicles. Attention is also given to space power systems, flight-vehicle structural strength, and flight-vehicle control systems. B.J.

N89-10078*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
AUTOMATION OF SPACECRAFT CONTROL CENTERS
ROBERT DUTILLY *In its* Proceedings of 1987 Goddard Conference on Space Applications of Artificial Intelligence (AI) and Robotics 9 p 1987
Avail: NTIS HC A99/MF E03 CSCL 05A

The objective is to describe the further automation of the Payload Operations Control Centers, specifically the Mission Operations Room, by using a series of expert systems interconnected together. The feasibility of using expert systems in the Mission Operations Room is presently being determined. The expert system under development is called the Communications Link Expert Assistance Resource (CLEAR) project. It is the first control center expert system being designed and implemented at Goddard. It will demonstrate the feasibility and practicality of expert systems in a real-time control center environment. There is a two-fold purpose. First is to briefly describe the present effort of the CLEAR expert system under development. The second is to describe how a series of interacting expert systems could be developed to almost totally automate the Mission Operations Room within the control center. How these expert systems would be put together and what functions they could perform in the control center is described. These efforts will provide a great deal of applicability toward the automation of the space station. Author

N89-10084*# Ford Aerospace and Communications Corp., College Park, MD. Space Missions Div.
MAINTAINING CONSISTENCY BETWEEN PLANNING HIERARCHIES: TECHNIQUES AND APPLICATIONS
DAVID R. ZOCH *In* NASA, Goddard Space Flight Center, Proceedings of 1987 Goddard Conference on Space Applications of Artificial Intelligence (AI) and Robotics 18 p 1987
Avail: NTIS HC A99/MF E03 CSCL 05A

In many planning and scheduling environments, it is desirable to be able to view and manipulate plans at different levels of abstraction, allowing the users the option of viewing and manipulating either a very detailed representation of the plan or a high-level more abstract version of the plan. Generating a detailed plan from a more abstract plan requires domain-specific planning/scheduling knowledge; the reverse process of generating a high-level plan from a detailed plan Reverse Plan Maintenance, or RPM) requires having the system remember the actions it took based on its domain-specific knowledge and its reasons for taking those actions. This reverse plan maintenance process is described as implemented in a specific planning and scheduling tool, The Mission Operations Planning Assistant (MOPA), as well as the applications of RPM to other planning and scheduling problems; emphasizing the knowledge that is needed to maintain the correspondence between the different hierarchical planning levels. Author

N89-12596*# Control Dynamics Co., Huntsville, AL.
SPACE STATION DOCKING MECHANISM DYNAMIC TESTING
THOMAS G. HOWSMAN and JOHN R. GLAESE *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 168-175 1988
Avail: NTIS HC A21/MF A01 CSCL 22/2

A prototype docking mechanism for the Space Station was designed and fabricated for NASA. This docking mechanism is actively controlled and uses a set of electromechanical actuators for alignment and load attenuation. Dynamic tests are planned using the Marshall Space Flight Center's 6-DOF Motion Simulator. The proposed tests call for basic functionality verification as well as complete hardware-in-the-loop docking dynamics simulations. Author

N89-12842*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
IMPROVED DOCKING ALIGNMENT SYSTEM Patent Application
LEO G. MONFORD, inventor (to NASA) 15 Sep. 1988 19 p

(NASA-CASE-MSC-21372-1; NAS 1.71:MSC-21372-1; US-PATENT-APPL-SN-246595) Avail: NTIS HC A03/MF A01 CSCL 14/2

Improved techniques are provided for the alignment of two objects. The present invention is particularly suited for 3-D translation and 3-D rotational alignment of objects in outer space. A camera is affixed to one object, such as a remote manipulator arm of the spacecraft, while the planar reflective surface is affixed to the other object, such as a grapple fixture. A monitor displays in real-time images from the camera such that the monitor displays both the reflected image of the camera and visible marking on the planar reflective surface when the objects are in proper alignment. The monitor may thus be viewed by the operator and the arm manipulated so that the reflective surface is perpendicular to the optical axis of the camera, the roll of the reflective surface is at a selected angle with respect to the camera, and the camera is spaced a pre-selected distance from the reflective surface. NASA

N89-13452*# Martin Marietta Corp., Denver, CO. Astronautics Group.

ORBITAL TRANSFER VEHICLE CONCEPT DEFINITION AND SYSTEM ANALYSIS STUDY, 1985. VOLUME 2: OTV CONCEPT DEFINITION AND EVALUATION. BOOK 4: OPERATIONS Final Report, Jul. 1984 - Oct. 1985

JACK C. MITCHELL and J. T. KEELEY Aug. 1985 202 p Revised, July 1987

(Contract NAS8-36108)

(NASA-CR-183545; NAS 1.26:183545; MCR-86-2601-VOL-2-BK-4-REV) Avail: NTIS HC A10/MF A01 CSCL 22/2

The benefits of the reusable Space Shuttle and the advent of the new Space Station hold promise for increasingly effective utilization of space by the scientific and commercial as well as military communities. A high energy reusable oribital transfer vehicle (OTV) represents an additional capability which also exhibits potential for enhancing space access by allowing more ambitious missions and at the same time reducing launch costs when compared to existing upper stages. This section, Vol. 2: Book 4, covers launch operations and flight operations. The launch operations section covers analyses of ground based and space based vehicles, launch site facilities, logistics requirements, propellant loading, space based maintenance and aft cargo carrier access options. The flight operations sections contain summary descriptions of ground based and space based OTV missions, operations and support requirements, and a discussion of fleet implications. Author

N89-13483*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

RESULTS OF EVA/MOBILE TRANSPORTER SPACE STATION TRUSS ASSEMBLY TESTS

JUDITH J. WATSON, WALTER L. HEARD, JR., HAROLD G. BUSH, M. S. LAKE, J. K. JENSEN, R. E. WALLSOM, and J. E. PHELPS (PRC Kentron, Inc., Hampton, Va.) Nov. 1988 31 p

(NASA-TM-100661; NAS 1.15:100661) Avail: NTIS HC A03/MF A01 CSCL 22/2

Underwater neutral buoyance tests were conducted to evaluate the use of a Mobile Transporter concept in conjunction with EVA astronauts to construct the Space Station Freedom truss structure. A three-bay orthogonal tetrahedral truss configuration with a 15 foot square cross section was repeatedly assembled by a single pair of pressure suited test subjects working from the Mobile Transporter astronaut positioning devices (mobile foot restraints). The average unit assembly time (which included integrated installation of utility trays) was 27.6 s/strut, or 6 min/bay. The results of these tests indicate that EVA assembly of space station size structures can be significantly enhanced when using a Mobile Transporter equipped with astronaut positioning devices. Rapid assembly time can be expected and are dependent primarily on the rate of translation permissible for on-orbit operations. The concept used to demonstate integrated installation of utility trays requires minimal EVA handling and consequentially, as the results show, has little impact on overall assembly time. Author

N89-15140# National Aerospace Lab., Amsterdam (Netherlands). Space Div.

INTRODUCTION TO POSSIBLE MEANS OF EXPERIMENT OPERATIONS ON THE SPACE STATION

J. P. B. VREEBURG 11 Jan. 1988 49 p Sponsored by the Netherlands Agency for Aerospace Programs, Delft

(NLR-TR-88009-U; ETN-89-93890; AD-B127688L) Avail: NTIS HC A03/MF A01

Space station system design, components, and utilization characteristics are reviewed. A case study of a man-tended free flyer payload is discussed. ESA

N89-16896*# Sterling Federal Systems, Inc., Palo Alto, CA.

MODIFICATIONS TO THE NASA AMES SPACE STATION PROXIMITY OPERATIONS (PROX OPS) SIMULATOR

ADAM BRODY Oct. 1988 10 p

(Contract NAS2-11555)

(NASA-CR-177510; NAS 1.26:177510) Avail: NTIS HC A02/MF A01 CSCL 14/2

As the United States is approaching an operational space station era, flight simulators are required to investigate human design and performance aspects associated with orbital operations. Among these are proximity operations (PROX OPS), those activities occurring within a 1-km sphere of Space Station including rendezvous, docking, rescue, and repair. The Space Station Proximity Operations Simulator at NASA Ames Research Center was modified to provide the capability for investigations into human performance aspects of proximity operations. Accurate flight equations of motion were installed to provide the appropriate visual scene to test subjects performing simulated missions. Also, the flight control system was enhanced by enabling pilot control over thruster acceleration values. Currently, research is under way to examine human performance in a variety of mission scenarios. Author

N89-17393*# Grumman Aerospace Corp., Bethpage, NY. Space Systems.

EXTRAVEHICULAR ACTIVITIES LIMITATIONS STUDY. VOLUME 2: ESTABLISHMENT OF PHYSIOLOGICAL AND PERFORMANCE CRITERIA FOR EVA GLOVES Final Report

JOHN M. OHARA, MICHAEL BRIGANTI, JOHN CLELAND, and DAN WINFIELD (Research Triangle Inst., Research Triangle Park, NC.) 1988 175 p

(Contract NAS9-17702)

(NASA-CR-172099; NAS 1.26:172099; AS-EVALS-FR-8701-VOL-2) Avail: NTIS HC A08/MF A01 CSCL 06/19

One of the major probelms faced in Extravehicular Activity (EVA) glove development has been the absence of concise and reliable methods to measure the effects of EVA gloves on human hand capabilities. This report describes the development of a standardized set of tests designed to assess EVA-gloved hand capabilities in six measurement domains: Range of Motion, Strength, Tactile Perception, Dexterity, Fatigue, and Comfort. Based on an assessment of general human hand functioning and EVA task requirements several tests within each measurement domain were developed to provide a comprehensive evaluation. All tests were designed to be conducted in a glove box with the bare hand as a baseline and the EVA glove at operating pressure. A test program was conducted to evaluate the tests using a representative EVA glove. Eleven test subjects participated in a repeated-measures design. The report presents the results of the tests in each capability domain. Author

N89-18039*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

INTERACTIVE ORBITAL PROXIMITY OPERATIONS PLANNING SYSTEM

ARTHUR J. GRUNWALD and STEPHEN R. ELLIS Nov. 1988

48 p
(NASA-TP-2839; A-88091; NAS 1.60:2839) Avail: NTIS HC A03/MF A01 CSCL 05/8

An interactive graphical proximity operations planning system was developed, which allows on-site design of efficient, complex, multiburn maneuvers in a dynamic multispacecraft environment. Maneuvering takes place in and out of the orbital plane. The difficulty in planning such missions results from the unusual and counterintuitive character of orbital dynamics and complex time-varying operational constraints. This difficulty is greatly overcome by visualizing the relative trajectories and the relevant constraints in an easily interpretable graphical format, which provides the operator with immediate feedback on design actions. The display shows a perspective bird's-eye view of a Space Station and co-orbiting spacecraft on the background of the Station's orbital plane. The operator has control over the two modes of operation: a viewing system mode, which enables the exporation of the spatial situation about the Space Station and thus the ability to choose and zoom in on areas of interest; and a trajectory design mode, which allows the interactive editing of a series of way points and maneuvering burns to obtain a trajectory that complies with all operational constraints. A first version of this display was completed. An experimental program is planned in which operators will carry out a series of design missions which vary in complexity and constraints. Author

N89-18516*# Little (Arthur D.), Inc., Cambridge, MA.
ADVANCED EXTRAVEHICULAR ACTIVITY SYSTEMS REQUIREMENTS DEFINITION STUDY Final Report
Aug. 1988 131 p
(Contract NAS9-17894)
(NASA-CR-172111; NAS 1.26:172111) Avail: NTIS HC A07/MF A01 CSCL 22/2

A study to define the requirements for advanced extravehicular activities (AEVA) was conducted. The purpose of the study was to develop an understanding of the EVA technology requirements and to map a pathway from existing or developing technologies to an AEVA system capable of supporting long-duration missions on the lunar surface. The parameters of an AEVA system which must sustain the crewmembers and permit productive work for long periods in the lunar environment were examined. A design reference mission (DRM) was formulated and used as a tool to develop and analyze the EVA systems technology aspects. Many operational and infrastructure design issues which have a significant influence on the EVA system are identified. NASA

N89-19809*# Essex Corp., Huntsville, AL.
ADVANCED EXTRAVEHICULAR ACTIVITY SYSTEMS REQUIREMENTS DEFINITION STUDY. PHASE 2: EXTRAVEHICULAR ACTIVITY AT A LUNAR BASE Final Report
VALERIE NEAL, NICHOLAS SHIELDS, JR., GERALD P. CARR, WILLIAM POGUE, HARRISON H. SCHMITT, and ARTHUR E. SCHULZE (Lovelace Scientific Resources, Inc., Albuquerque, NM.) Sep. 1988 160 p
(Contract NAS9-17779)
(NASA-CR-172117; NAS 1.26:172117) Avail: NTIS HC A08/MF A01 CSCL 06/11

The focus is on Extravehicular Activity (EVA) systems requirements definition for an advanced space mission: remote-from-main base EVA on the Moon. The lunar environment, biomedical considerations, appropriate hardware design criteria, hardware and interface requirements, and key technical issues for advanced lunar EVA were examined. Six remote EVA scenarios (three nominal operations and three contingency situations) were developed in considerable detail. B.G.

N89-19819*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SPACE STATION PAYLOAD OPERATIONS SCHEDULING WITH ESP2
KENNETH L. STACY and JOHN P. JAAP *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 7-13 Nov. 1988
Avail: NTIS HC A22/MF A01 CSCL 22/2

The Mission Analysis Division of the Systems Analysis and Integration Laboratory at the Marshall Space Flight Center is developing a system of programs to handle all aspects of scheduling payload operations for Space Station. The Expert Scheduling Program (ESP2) is the heart of this system. The task of payload operations scheduling can be simply stated as positioning the payload activities in a mission so that they collect their desired data without interfering with other activities or violating mission constraints. ESP2 is an advanced version of the Experiment Scheduling Program (ESP) which was developed by the Mission Integration Branch beginning in 1979 to schedule Spacelab payload activities. The automatic scheduler in ESP2 is an expert system that embodies the rules that expert planners would use to schedule payload operations by hand. This scheduler uses depth-first searching, backtracking, and forward chaining techniques to place an activity so that constraints (such as crew, resources, and orbit opportunities) are not violated. It has an explanation facility to show why an activity was or was not scheduled at a certain time. The ESP2 user can also place the activities in the schedule manually. The program offers graphical assistance to the user and will advise when constraints are being violated. ESP2 also has an option to identify conflict introduced into an existing schedule by changes to payload requirements, mission constraints, and orbit opportunities. Author

N89-20081*# Southern Univ., Baton Rouge, LA. Dept. of Electronics Engineering Technology.
FEASIBILITY OF USING HIGH TEMPERATURE SUPERCONDUCTING MAGNETS AND CONVENTIONAL MAGNETIC LOOP ANTENNAS TO ATTRACT OR REPEL OBJECTS AT THE SPACE STATION Final Report
MANJIT S. RANDHAWA *In* NASA, Lyndon B. Johnson Space Center, National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988, Volume 2 14 p Feb. 1989
Avail: NTIS HC A09/MF A01 CSCL 20/14

A study was undertaken to see if magnetic forces can be used at the Space Station to attract or repel spacecrafts such as the Orbital Manuevering Vehicle (OMV) or the Orbiter. A large magnet, in the form of a current loop, is assumed to be placed at the Space Station and another one on the spacecraft. The expression for the force between the two dipoles (loops) is obtained. Using a force of 15 Newtons (3.4 pounds) in order to move the spacecraft, the number of ampere-turn needed in the current loops was calculated at various distances between them. The expression for the force of attraction between a current loop and a soft magnetic material was also examined and the number of amp-turn needed to provide a force of one-tenth of a pound at various distances is also calculated. This one tenth of a pound force would be used in a life line system for the retrieval of an adrift crewman or tool at the Space Station. The feasibility of using conventional antenna on the Station and the incoming vehicle for attraction or repulsion was also examined. Author

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SPACE ENVIRONMENT

Includes description of the space environment and effects on Space Station subsystems. Includes requirements for Space Station to accommodate this environment.

A89-10595
SIMULATION FACILITIES COMPATIBILITY IN DESIGN FOR COMPATIBILITY IN SPACE
MURDOCH MCKINNON and LES WHITE (CAE Electronics, Ltd.,

Montreal, Canada) IN: Aerospace Behavioral Engineering Technology Conference, 6th, Long Beach, CA, Oct. 5-8, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 181-187.
(SAE PAPER 871716)

This paper considers simulation facilities related to space development, with special attention given to the major design and performance features of the Canada's Aft Crew Station Simulation Facility SIMFAC (which was built to support the development of the Shuttle Remote Manipulator System) and those of EUROSIUM, which is the simulation facility being currently developed to support the European Space Program. Consideration is also given to the simulation facility of the Mobile Servicing System, which will be required to interact with other elements of the Space Station and which will have both autonomous and telerobotic modes. A parallel is drawn between these simulation facilities and the Crew Station Research and Development Facility developed recently as a design and evaluation tool for future helicopter designs, whose workload and task evaluation facilities and the technology used may serve as examples for space simulation design. I.S.

A89-11197* National Aeronautics and Space Administration. White Sands Test Facility, NM.
THE BEHAVIOR OF OUTGASSED MATERIALS IN THERMAL VACUUMS
WILLIAM MAHONE and RANDY KAYS (NASA, White Sands Test Facility; Lockheed Engineering and Management Services Co., Inc., Las Cruces, NM) Journal of Environmental Sciences (ISSN 0022-0906), vol. 31, Sept.-Oct. 1988, p. 28-32. refs

Scientists at the NASA White Sands Test Facility (WSTF) are investigating the relationship between outgassing and condensation for aerospace materials in space-like environments. The WSTF throughput test method was validated by previous testing at WSTF using palmitic acid. Data from these tests were compared with data from other preliminary tests by using adipic and behenic acids. The comparison indicates that surface forces between outgassed molecules and the condensing surfaces cause the condensation flux to be different from the incident flux. These forces can also cause the evaporative flux to be different from the expected value. These discrepancies are discussed in terms of both potential and dynamic interactions of outgassed molecules with surfaces. Although these surface forces are noticeable, their overall effect on the test is minimal. Author

A89-12107#
MAN-MADE SPACE DEBRIS - DATA NEEDED FOR RATIONAL DECISION
STEPHEN GOROVE (Mississippi, University, University; International Institute of Space Law, Paris, France) IN: Colloquium on the Law of Outer Space, 30th, Brighton, England, Oct. 10-17, 1987, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 135-137. refs

This article starts with an emphasis on the growing risks arising from man-made space debris. It calls for a comprehensive study and review of essential data required for informed decision. The data relates not only to the various types of debris but also to the damage that each category of debris may cause and the likelihood of the latter's occurrence. The study and continuous assessment of the debris situation may be undertaken by an appropriate body of scientists, engineers and other professionals under UN auspices. Author

A89-12108#
SPACE POLLUTION
ALESIA MCCLOUD (Denver, University, CO) IN: Colloquium on the Law of Outer Space, 30th, Brighton, England, Oct. 10-17, 1987, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 142-146. refs

This article identifies chemical, biological, and radiological pollution sources incidental to current and contemplated outer space exploration. It discusses their negative and unforeseen environmental impact. Then, it surveys international agreements addressing space pollution issues and concludes that they lack the specificity necessary to prevent such inadvertent environmental damage. It is recommended that the scope of these agreements be enlarged to encompass cumulative damage to the outer space environment, and to provide a means for seeking redress and reparation of harm to it. Also urged is the creation of an advisory board to monitor outer space pollution and establish international environmental standards and a separate international regulatory body to enforce those standards. Author

A89-12109#
PREVENTION OF ORBITAL DEBRIS
DAVID ENRICO REIBEL (Institute for Security and Cooperation in Outer Space, Washington, D. C.) IN: Colloquium on the Law of Outer Space, 30th, Brighton, England, Oct. 10-17, 1987, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 147-154. refs

The sources of man-made orbital debris and the hazards it poses are reviewed, and technological and legal measures to reduce debris are recommended. Topics addressed include debris measurement and tracking, the high proportion of debris (50 percent of all orbiting objects) due to satellite fragmentations (especially ASAT tests and other military activities), the concentration of debris in LEO (where it is most hazardous to manned missions), the amount of debris from nonfunctioning satellites and from orbital operations, and current national and international regulations. Particular attention is given to GEO satellites, space commercialization, nuclear power sources, and space militarization. The recommendations focus on improved tracking and data dissemination, expanded research on debris removal, stronger regulations on payload design and orbital operations, and extending the ban on space weapons testing. T.K.

A89-12110#
ENVIRONMENTAL POLLUTION OF OUTER SPACE, IN PARTICULAR OF THE GEOSTATIONARY ORBIT
G. C. M. REIJNEN (Utrecht, Rijksuniversiteit, Netherlands) IN: Colloquium on the Law of Outer Space, 30th, Brighton, England, Oct. 10-17, 1987, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 155-162. refs

The factors contributing to the space pollution are reviewed, and the international agreements intended to limit pollution and regulate the use of GEO slots and radio frequencies by communication satellites are discussed from a legal perspective. Topics examined include atmospheric pollution by launch vehicles, the general problem of space debris, the special problems of GEO satellites, the claims of equatorial countries to rights over GEO slots above their territory (and UN treaty provisions clearly denying such rights), radio pollution from GEO (and the overlapping jurisdictions of COPUOS and ITU in regulating it), contamination of other celestial bodies with earth materials, and back-contamination of the earth with extraterrestrial biological materials. Particular attention is given to the provisions of UN space treaties and their specific applicability. T.K.

A89-12111#
CURRENT U.S. INITIATIVES TO CONTROL SPACE DEBRIS
F. KENNETH SCHWETJE (USAF, International Law Div., Washington, DC) IN: Colloquium on the Law of Outer Space, 30th, Brighton, England, Oct. 10-17, 1987, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 163-171. refs

The potential dangers posed by man-made space debris are reviewed, and U.S. efforts to limit debris are described. It is pointed out that the number of tracked and untracked objects is increasing rapidly and will continue to do so, with serious implications for manned missions in LEO; operation at high risk levels or redesign of spacecraft to withstand debris impact are considered unacceptable options. Accelerated decay, disposal orbits, or spacecraft retrieval are discussed as methods for reducing debris; the international legislation applying to such operations is outlined; DOD, USAF, and SDIO policy statements indicating an interest in limiting debris are cited; and the NORAD debris tracking and

cataloging program and the NASA 10-year debris-assessment plan are briefly characterized. T.K.

A89-12576#
SURFACE EFFECTS OF SATELLITE MATERIAL OUTGASSING PRODUCTS
B. E. WOOD, W. T. BERTRAND, R. J. BRYSON, B. L. SEIBER (Calspan Corp., Arnold Air Force Station, TN), PATRICK FALCO, M. (USAF, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH) et al. Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 2, Oct. 1988, p. 289-295. USAF-sponsored research. Previously cited in issue 19, p. 2974, Accession no. A87-43090. refs

A89-12659
SPACE SURVEILLANCE - THE SMART CATALOG
DAVID G. COOKE (USAF, Space Surveillance Div., Peterson AFB, CO) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 569-575.
(AAS PAPER 87-450)

The current satellite population includes about 6800 objects in both near earth and deep space, much of which is satellite debris or rocket bodies left in orbit after the deployment of a payload or an operational satellite. This paper discusses the concept of a facility (termed 'SMART Catalog') which would be tasked with the job of characterizing the space debris environment and would share data with the Space Surveillance Center. The SMART Catalog will be a hybrid data base unlike any in existence today; it will include such types of data as orbital elements, uncorrelated observations, and unknown objects. Data will be sampled from both optical and radar sensors of the Space Surveillance Network, a system of sensors which make an average of 40,000 satellite observations every day and which have the capacity to catalog three or four times more data than is the level of the current catalog. I.S.

A89-12670
MODELLING UNTRACKABLE ORBITAL DEBRIS ASSOCIATED WITH A TRACKED SPACE DEBRIS CLOUD
ROBERT D. CULP and RONALD A. MADLER (Colorado, University, Boulder) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 775-790. refs
(AAS PAPER 87-472)

Untrackable satellite fragments in the 1-10 cm range associated with an individual tracked debris cloud are modeled using a computer in an attempt to obtain a more accurate estimate of their number and the hazard they represent for space operations. A sample application of the model to the calculation of the collision hazard for a typical Space Station orbit is used to illustrate the importance of accounting for the untrackable debris in evaluating the threat to large space structures. V.L.

A89-12671
THE EFFECTS OF ECCENTRICITY ON THE EVOLUTION OF AN ORBITING DEBRIS CLOUD
DAVID B. SPENCER (Aerospace Corp., Los Angeles, CA) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 1. San Diego, CA, Univelt, Inc., 1988, p. 791-807. refs
(Contract F04701-85-C-0086)
(AAS PAPER 87-473)

Following an orbital break-up of a spacecraft, a cloud of debris is formed, and evolves into unique orbits with respect to the parent body. A formulation of the debris cloud motion and evolutionary characteristics are described for a disintegrating body that is in an initially elliptical orbit. Results for different values of eccentricity and event time of periapsis passage are presented, and are compared to the results for the circular orbit case. Additionally, the consequences of assuming a circular orbit instead of an elliptical orbit for the object breaking up are discussed. The actual cloud size and collision hazard posed by the cloud on other spacecraft passing through it are also discussed. Author

A89-13936
APPLICATIONS OF HIGH TEMPERATURE CHEMISTRY TO SPACE RESEARCH
EDMOND MURAD (USAF, Geophysics Laboratory, Hanscom AFB, MA) IN: Symposium on High Temperature Materials Chemistry - IV, Honolulu, HI, Oct. 19-23, 1987, Proceedings. Pennington, NJ, Electrochemical Society, Inc., 1988, p. 375-381. refs

This paper discusses the effect of exposure of a spacecraft to the ambient atmosphere of low earth orbits (250-400 km) on the materials of the spacecraft surface. The results of intentional and unintentional material experiments on the Space Shuttle are presented, indicating that the interactions between the surfaces and the low-orbit atmosphere leads to effects resembling those of high-temperature vaporization and oxidation, which can lead to erosion or mass gain in the exposed surfaces and can change the physical properties of the materials. The specific effects that these changes might have on various instruments and sensors on low earth orbit stations are discussed. I.S.

A89-15408
THE BREAKDOWN CHARACTERISTICS OF OUTGASSING DOMINATED VACUUM REGIONS
S. A. MERRYMAN, A. J. BANDY, and L. B. GORDON (Auburn University, AL) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 763-765. SDIO-supported research.
(Contract DNA001-85-C-0183)

The prospect of using the space vacuum as an electrical insulator for high power/high voltage applications makes it necessary to determine the electrical breakdown characteristics of this region. A dominating factor in the breakdown characterization is the effect of material outgassing on the insulating properties of a vacuum region. Outgassing properties are studied here for commonly used insulating materials such as G-10 fiberglass laminates, Teflon, and polyethylene. Preliminary measurements of the outgassing species, the effect of temperature on the rate of outgassing, and the electrical breakdown voltage as a result of outgassing are presented. C.D.

A89-17674*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
THE INDUCED ENVIRONMENT AROUND SPACE STATION
MARSHA R. TORR (NASA, Marshall Space Flight Center, Huntsville, AL) and D. G. TORR (Science and Engineering Associates, Inc., Huntsville, AL) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 23 p. refs
(IAF PAPER 88-095)

The potential impact of the International Space Station on its immediate environment is discussed, summarizing the results of recent investigations by NASA working groups. Consideration is given to the neutral-gas environment, induced photon emission, particulate contamination, the ionized environment, the Induced-environment Monitoring Package proposed for inclusion in the Space Station equipment, and recommendations for further research. Diagrams, drawings, graphs, and tables of numerical data are provided. T.K.

A89-17846#
THE ORBITAL DEBRIS ISSUE - A STATUS REPORT
DARREN MCKNIGHT (U.S. Air Force Academy, Colorado Springs, CO), MALCOLM WOLFE, VLADIMIR CHOBOTOV (Aerospace Corp., El Segundo, CA), DAVID COOKE (Canadian Forces, Canada), ROBERT CULP (Colorado, University, Boulder) et al. IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 11 p. refs
(IAF PAPER 88-519)

New analytical tools, computer models, and data-gathering modes have been developed to address the expanding menace

to spacecraft that is posed by the growth of orbital debris. The legal aspects of orbital debris have been discussed at international forums on space law since an international orbital debris workshop was held at NASA's Johnson Space Center in 1982; in addition, a USAF study was conducted in 1986-1987 that led to a DOD debris policy statement. Attention is given to the status of debris hazards in LEO and GEO. A Presidential Directive On Space Policy promulgated on February 11, 1988 has mandated the minimization of debris creation by future operations in orbit. O.C.

A89-17847#
COLLISION PROBABILITY OF SPACECRAFT WITH MAN-MADE DEBRIS
A. S. GANESHAN, S. C. RATHNAKARA, N. S. GOPINATH, and P. PADMANABHAN (ISRO, Flight Dynamics Div., Bangalore, India) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 9 p. refs
(IAF PAPER 88-522)

A probabilistic modeling has been conducted of the collision hazard probabilities faced by the Indian Remote Sensing (IRS) satellite due to man-made debris. This Monte Carlo approach assumes collision to occur when both the operational spacecraft and the debris come within an a priori specified volume in orbital space. This approach is also applied to the collision probabilities between two collocated geostationary satellites. The IRS's probability of debris collision is about 7.34 x 10 to the -5th impacts/year; collocated geostationary satellites' collision probability is 6.3 x 10 to the -7th. O.C.

A89-17860*# Arizona Univ., Tucson.
ECONOMICAL IN-SITU PROCESSING FOR ORBITAL DEBRIS REMOVAL
KUMAR RAMOHALLI (Arizona, University, Tucson) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 8 p. NASA-supported research. refs
(IAF PAPER 88-576)

This paper proposes and develops the first description of a concept for the removal of large pieces of orbital debris. After a brief discussion of the growing importance of the general problem of orbital debris, the idea of utilizing local resources for clearing the debris is introduced. A description of the initial terrestrially working hardware and future projections for this Autonomous Space Processor for Orbital Debris concludes this paper. Author

A89-17939*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE EFFECT OF THE NEAR EARTH MICROMETEOROID ENVIRONMENT ON A HIGHLY REFLECTIVE MIRROR SURFACE
MICHAEL J. MIRTICH, HERMAN MARK, and WILLIAM R. KERSLAKE (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 26th, Reno, NE, Jan. 11-14, 1988. 39 p. Previously announced in STAR as N88-29833. refs
(AIAA PAPER 88-0026)

A resurgence of interest in placing large solar concentrator solar dynamic systems in space for power generation has brought up again a concern for maintaining the integrity of the optical properties of highly specular reflecting surfaces in the near earth space environment. One of the environmental hazards needing evaluation is the micrometeoroid environment. It has been shown that highly reflective polished metals and thin film coatings degrade when exposed to simulated micrometeoroids in the lab. At NASA-Lewis, a shock tube was used to simulate the phenomenon of micrometeoroid impact by accelerating micron sized particles to hypervelocities. Any changes in the optical properties of surfaces exposed to this impact were then evaluated. The degradation of optical properties of polished metals and thin metallic films after exposure to simulated micrometeoroids was determined as a function of impacting kinetic energy area of the particles. A calibrated sensor was developed to not only detect the micrometeoroid environment, but also to evaluate the degradation of the optical properties of thin aluminum films in space. Results of the simulation are presented and discussed. Author

A89-18439
MODELING THE EFFECTS CONNECTED WITH THE INFLUENCE OF THE MAGNETIC AND SOLAR SHADOW FROM SATELLITE STRUCTURAL ELEMENTS ON RESULTS OF MEASUREMENTS OF ELECTRIC FIELDS AND PARTICLE FLUXES [MODELIROVANIE EFFEKTOV, SVIAZANNYKH S VLIIANIEM MAGNITNOI I SOLNECHNOI TENI OT ELEMENTOV KONSTRUKTSII SPUTNIKA NA REZUL'TATY IZMERENII ELEKTRICHESKIKH POLEI I POTOKOV CHASTITS]
M. M. TSONEV and G. A. STANEV (B'lgarska Akademiia na Naukite, Tsentralna Laboratoriia za Kosmicheski Izsledvaniia, Sofia, Bulgaria) Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 26, Sept.-Oct. 1988, p. 731-737. In Russian. refs

A89-19945#
MAINTENANCE OF MICROGRAVITY ENVIRONMENT ON THE SPACE STATION - ON THE MICROGRAVITY ENVIRONMENT ANALYSIS AND VIBRATION ISOLATION
KATSUHIDE KITAMURA, KENJI SAKANO, KOJI TANIDA, KOICHI SHOJI, MUNETAKA KURIBAYASHI et al. Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 28, July 1988, p. 207-212. In Japanese, with abstract in English.

In a space facility on circular orbit around the earth, a state of global nongravitation is realized but microgravity exists. In order to suppress microgravity force and maintain high quality microgravity level, various plans are examined. This paper describes: (1) analytical evaluation methods of microgravity level in the facility, and (2) control technique to restrain the level of machines by vibration-proof devices. The first part treats analysis of microgravity environment in a Space Station, examination of analysis program and mathematical models including gravity gradient, atmospheric drag, guidance navigation, and control simulation as well as low-frequency and high-frequency dynamics. The second part deals with vibration suppression method for microgravity, apparatus utilizing electromagnetic suspension, and control approach of three axes, six degrees of freedon. Author

A89-21080
APPLICATION OF COMPOSITE MATERIALS TO SPACE STRUCTURES
D. G. ZIMCIK (CDC, Communications Research Centre, Ottawa, Canada) (Canadian Engineering Centennial Convention, Montreal, Canada, May 1987) Canadian Society for Mechanical Engineering, Transactions (ISSN 0315-8977), vol. 12, no. 2, 1988, p. 49-56. refs

Material requirements for space structures are reviewed with emphasis on composite applications. Specific examples of the use of both polymer and metallic matrix composite in space structures are examined, and problems associated with environmental effects are discussed. The discussion also covers future trends in space structures and their implications for composite materials, as well as examples of current work in polymer and metal matrix composites aimed at satisfying the requirements for future space structures. V.L.

A89-21941
AN INTERSTELLAR DUST COMPONENT RICH IN C-12
R. D. ASH, M. M. GRADY, I. P. WRIGHT, C. T. PILLINGER (Open University, Milton Keynes, England), and J. W. ARDEN (Oxford University, England) Nature (ISSN 0028-0836), vol. 336, Nov. 17, 1988, p. 228-230. Research supported by SERC. refs

The results of an analysis of an acid-resistant residue from the Allende meteorite, extensively combusted in oxygen at low temperatures to remove isotopically normal carbon, is reported. The analysis reveals the presence of a small amount of carbon with a C-12/C-13 ratio close to 120, well above the value of 89 + or - 3 found in terrestrial samples or bulk meteorites. This component is denoted C-lambda. Stellar evolutionary processes favor lowering of the C-12/C13 ratio; hence C-lambda, which has a combustion temperature consistent with graphite, might be a primitive type of interstellar material. C.D.

A89-22775
INTRODUCTION TO THE SPACE ENVIRONMENT
THOMAS F. TASCIONE Malabar, FL, Orbit Book Co., 1988, 125 p. refs

A89-23222
A NOVA OUTBURST SCENARIO FOR GX 1 + 4 SPIN-DOWN EPISODE
R. K. MANCHANDA (University College, Canberra, Australia; Tata Institute of Fundamental Research, Bombay, India) Astrophysics and Space Science (ISSN 0004-640X), vol. 150, no. 1, Dec. 1988, p. 31-41. refs

X-ray spectral data of the source during 1982-1987 suggest that the observed low state of the source intensity could have arisen due to additional absorption of the X-ray flux by material surrounding the X-ray source, which could have come from the companion star during a nova outburst. The accretion models do not explain the rapid spin-down of the pulsar. If the spin-down is caused by the nova outburst, it is suggested that period slow-down can occur due to mechanical braking of the pulsar generated by the increased moment of inertia. Author

A89-23448
IS THE SPACE ENVIRONMENT AT RISK?
G. B. FIELD (Harvard University, Cambridge, MA), M. J. REES (Cambridge University, England), and D. N. SPERGEL (Princeton University, NJ) Nature (ISSN 0028-0836), vol. 336, Dec. 29, 1988, p. 725, 726.

The problems posed by pollution of near-earth space are reviewed, and possible solutions are considered. Measures that need to be taken to monitor the space environment, restrict the growth of space debris and the use of nuclear reactors in space, and emphasize peaceful pursuits in space are discussed. The use of space to verify arms control treaties and the need to ban the development, testing, and deployment of ASAT systems is addressed. C.D.

A89-23809
EXHAUST JET CONTAMINATION OF SPACECRAFT [STRAHLBEAUFSCHLAGUNG AN RAUMFAHRZEUGEN]
ROLF-D. BOETTCHER, CARL DANKERT, GEORG DETTLEFF, GEORG KOPPENWALLNER, and HUBERT LEGGE (DFVLR, Institut fuer experimentelle Stroemungsmechanik, Goettingen, Federal Republic of Germany) DFVLR-Nachrichten (ISSN 0011-4901), Nov. 1988, p. 8-11. In German.

The effects of exhaust jet contamination on spacecraft are studied, and methods of coping with them are considered. Models of the exhaust flow and of the contamination are described, and experimental investigations of such contamination are reviewed. Applications of the findings are addressed. C.D.

A89-23976#
PRELIMINARY EXPERIMENTS OF ATOMIC OXYGEN GENERATION FOR SPACE ENVIRONMENTAL TESTING
MICHIO NISHIDA (Kyoto University, Japan) and YASUO WATANABE (National Aerospace Laboratory, Chofu, Japan) Japan Society for Aeronautical and Space Sciences, Transactions (ISSN 0549-3811), vol. 31, Nov. 1988, p. 123-133. refs

Preliminary experiments of producing atomic oxygen for space environmental testing were conducted. To confirm the generation of O-atoms and to examine possibility of forming a molecular beam from the supersonic freejet, population densities of the electronic excitation levels 3p3 P and 3p5 P of atomic oxygen were measured along the freejet centerline. The results show that the population densities satisfied the low earth orbit conditions. Author

A89-24245#
MODEL FOR RADIATION CONTAMINATION BY OUTGASSING FROM SPACE PLATFORMS
STEPHEN J. YOUNG and RONALD R. HERM (Aerospace Corp., Infrared Sciences Dept., El Segundo, CA) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 25, Nov.-Dec. 1988, p. 413-419. Previously cited in issue 08, p. 1059, Accession no. A87-22416. refs
(Contract F04701-85-C-0086)

A89-25338*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
CONTAMINATION CONCERNS IN THE MODULAR CONTAINERLESS PROCESSING FACILITY
P. K. SESHAN and E. H. TRINH (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. refs
(AIAA PAPER 89-0403)

This paper describes the problems of the control and management of contamination in the Modular Containerless Processing Facility (MCPF), that is being currently developed at the JPL for the Space Station, and in the MCPF's precursor version, called the Drop Physics Module (DPM), which will be carried aboard one or more Space Shuttle missions. Attention is given to the identification of contamination sources, their mode of transport to the sample positioned within the chamber, and the protection of the sample, as well as to the mathematical simulatiom of the contaminant transport. It is emphasized that, in order to choose and implement the most appropriate contamination control strategy for each investigator, a number of simplified mathematical simulations will have to be developed, and ground-based contamination experiments will have to be carried out with identical materials. I.S.

A89-25372#
A CAD METHOD FOR THE DETERMINATION OF FREE MOLECULE AERODYNAMIC AND SOLAR RADIATION FORCES AND MOMENTS
C. A. SEDLUND (General Dynamics Corp., Space Systems Div., San Diego, CA) and L. H. SENTMAN (Illinois, University, Urbana) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 10 p. Research supported by Lockheed Missiles and Space Co., Inc.
(AIAA PAPER 89-0455)

A CAD program to calculate free molecule and solar force and moment coefficients was developed and applied to the Space Station with three different approximations of the structural truss. The primary result is that the geometrical model of the spacecraft, rather than the parameters such as the temperature of the reflected molecules or reflectance of the surface, is the major factor in calculating accurate force and moment coefficients for a complicated spacecraft such as the Space Station. The effect of the truss approximation on the force coefficients is predictable, with the magnitudes of the coefficients ranked by the size of the truss approximation. The effect of the truss approximation on the moment coefficients is more complex and shading effects cause significant irregularities in the moment coefficients as the angle of attack varies. Author

A89-25405*# TRW, Inc., Redondo Beach, CA.
LARGE STRUCTURE CURRENT COLLECTION IN PLASMA ENVIRONMENTS
N. JOHN STEVENS (TRW Power and Systems Integration Laboratory, Redondo Beach, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(Contract NAS3-24659)
(AIAA PAPER 89-0496)

The floating potential, relative to the space plasma, of large satellites proposed for future missions is an important factor in the current balance between the plasma particle collection of biased surfaces and exposed conductors. To solve this balance, a knowledge of the plasma current collection processes is required. One of the unknowns in these relationships is the current collection of large areas of conducting surfaces. Only limited experimental data is available on this collection process. Data from one of the few available tests is used herein to verify the applicability of a plasma collection model for large surfaces. The model is then applied to determine the floating potential of the NASA Space Station. Author

A89-25754
USING LABORATORY X-RAY AND COBALT-60 IRRADIATIONS TO PREDICT CMOS DEVICE RESPONSE IN STRATEGIC AND SPACE ENVIRONMENTS
D. M. FLEETWOOD, P. S. WINOKUR, and J. R. SCHWANK (Sandia National Laboratories, Albuquerque, NM) (IEEE, DNA, NASA, and DOE, Annual Conference on Nuclear and Space Radiation Effects, 25th, Portland, OR, July 12-15, 1988) IEEE Transactions on Nuclear Science (ISSN 0018-9499), vol. 35, Dec. 1988, pt. 1, p. 1497-1505. Research supported by DNA. refs
(Contract DE-AC04-76DP-00789)

The postirradiation response of CMOS transistors with 30-60-nm gate oxides is investigated as a function of radiation energy, total dose, dose rate, and annealing time. Measurements of threshold voltage, oxide-trapped charge, and interface traps are reported for times ranging from 10 ms to 4 months following LINAC, Co-60, Cs-137, and 10-keV X-ray irradiation. Exposure dose rates vary by 11 orders of magnitude: from 0.05 to 6 Grad(SiO2)/sec. To within the + or - 10 percent uncertainty in the overall dosimetry, no 'true' dose-rate effects on MOS device response are observed. Interface trap and oxide-trapped charge densities are linear with total dose. Preliminary recommendations are made for lot acceptance testing of hardened CMOS circuits and devices intended for use in space and strategic environments. I.E.

A89-25760
DOSE-RATE EFFECTS ON THE TOTAL-DOSE THRESHOLD-VOLTAGE SHIFT OF POWER MOSFETS
R. D. SCHRIMPF, P. J. WAHLE, D. B. COOPER, K. F. GALLOWAY (Arizona, University, Tucson), and R. C. ANDREWS (Motorola, Inc., Government Electronics Group, Chandler, AZ) (IEEE, DNA, NASA, and DOE, Annual Conference on Nuclear and Space Radiation Effects, 25th, Portland, OR, July 12-15, 1988) IEEE Transactions on Nuclear Science (ISSN 0018-9499), vol. 35, Dec. 1988, pt. 1, p. 1536-1540. Research supported by Motorola, Inc. refs

Radiation-hardened and unhardened n-channel power MOSFETs were tested at dose rates approaching space-radiation levels. The hardened parts exhibited large superrecovery effects during and after very low total doses of ionizing radiation. The superrecovery was attributed to in situ interface-trap formation. These positive threshold shifts and the accompanying interface traps can reduce current-drive capability in power MOSFETs. The impact on space-system use is discussed. The threshold-voltage shift of the positively biased unhardened parts was dominated by generation of oxide trapped charge at all dose-rates; the threshold voltage of these parts decreased monotonically at all doses and dose rates examined. I.E.

A89-28440#
AN ANALYSIS OF GPS ELECTROSTATIC DISCHARGE RATES
J. W. HAFFNER (Rockwell International Corp., Seal Beach, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 8 p. refs
(AIAA PAPER 89-0616)

Solar wind statistics and energy density considerations were used to calculate the probability of hot plasma reaching the orbit of GPS spacecraft. The results of these calculations were that the spacecraft should experience hot plasma 0.3 percent of the time (1 day/year). However, scaling from several laboratory and on-orbit (at GEO) measurements showed that, when hot plasma is present, the GPS spacecraft would be expected to experience several hundred discharges per hour. Of the various techniques considered for reducing or eliminating these discharges, conductive coatings (such as indium/tin oxide) and astroquartz appears to be the most promising. Author

A89-29296* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
REACTION OF ATOMIC OXYGEN (O/3P/) WITH VARIOUS POLYMER FILMS
MORTON A. GOLUB and THEODORE WYDEVEN (NASA, Ames Research Center, Moffett Field, CA) (Canadian High Polymer Forum, 24th, Ottawa, Canada, Aug. 5-7, 1987) Polymer Degradation and Stability (ISSN 0141-3910), vol. 22, 1988, p. 325-338. refs

An attempt is made to obtain the etch rates for various polymer films exposed to O(3P) downstream from, and out of the glow of, the O2 plasma. These rates are compared with published values from the following sources: etching in the glow of an O2 plasma, the Space Shuttle STS-8 flight experiment, and beam experiments. The etch rate data for Kapton fit a logarithmic plot (with a positive slope) of the reaction probability versus O(3P) impact energy. K.K.

A89-29503
UV/OZONE REMOVAL OF CONTAMINANTS IN SPACECRAFT ENVIRONMENTS
J. R. BLANCO (California State University, Northridge), R. J. CHAMPETIER (TRW, Inc., Redondo Beach, CA), and C. B. KALEM IN: Ultraviolet technology II; Proceedings of the Meeting, Orlando, FL, Apr. 4, 5, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 265-270.
(Contract F30602-85-C-0279)

The UV/ozone cleaning process has been studied as both a method for preventing contaminant films from forming on optical surfaces of a space sensor during storage, and for removing them from these surfaces after formation. Using mercury resonance lines at 253.7 and 184.9 nm and O2 pressures in the range of 0.00008 to 0.0004 torr, removal efficiencies from 1.8 x 10 to the -26th to 4.4 x 10 the -26 cu cm/photon were measured. Author

A89-29753
SPACECRAFT CHARGING AND ELECTROMAGNETIC EFFECTS ON GEOSTATIONARY SATELLITES [DECHARGES DIELECTRIQUES ET PERTURBATIONS ELECTROMAGNETIQUES SUR SATELLITES GEOSTATIONNAIRES]
JEAN-PIERRE MARQUE, JEAN GRANDO, ALAIN DELANNOY, and GERARD LABAUNE (ONERA, Chatillon-sous-Bagneux, France) Annales des Telecommunications (ISSN 0003-4347), vol. 43, Nov.-Dec. 1988, p. 615-624. In French. Research supported by DRET and CNES. refs

Various operational anomalies on satellites in geosynchronous orbit, chiefly occurring during magnetic storms, are attributed to spacecraft charging. The buildup of static charges on the surfaces of the spacecraft leads to various breakdown processes. Self-sustained discharges, characterized by strong electron emission out of the material, may occur on negatively charged films of polymer used, for example, as thermal blankets. The so-called blowoff emission occurs through a complex interaction of the electromagnetic field with the spacecraft. Author

A89-30100
THE HALO AROUND SPACECRAFT [OREOL VOKRUG KOSMICHESKIKH APPARATOV]
A. I. LAZAREV, S. V. AVAKIAN (Gosudarstvennyi Opticheskii Institut, Leningrad, USSR), and V. I. SEVAST'IANOV Priroda (ISSN 0032-874X), Feb. 1989, p. 100-102. In Russian.

Astronauts aboard various spacecraft (e.g., Soyuz 10 and 23, and the Space Shuttle Columbia in March 1982) have observed an intense glow or halo around the spacecraft. The most likely hypothesis is that this glow is caused by the excitation of the rarefied atmosphere surrounding the spaceraft by fluxes of molecules and ions of the upper layers of the earth's atmosphere. It is noted that this glow phenomenon can be counteracted by the proper choice of materials (e.g., polyethylene) to cover the spacecraft surface. B.J.

A89-30820*# Southwest Research Inst., San Antonio, TX.
A HYPERVELOCITY LAUNCHER FOR SIMULATED LARGE FRAGMENT SPACE DEBRIS IMPACTS AT 10 KM/S
R. J. TULLOS, W. M. GRAY, S. A. MULLIN (Southwest Research Institute, San Antonio, TX), and B. G. COUR-PALAIS (NASA, Johnson Space Center, Houston, TX) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers.

Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 1623-1628. refs
(AIAA PAPER 89-1345)

The background, design, and testing of two explosive launchers for simulating large fragment space debris impacts are presented. The objective was to develop a launcher capable of launching one gram aluminum fragments at velocities of 10 km/s. The two launchers developed are based on modified versions of an explosive shaped charge, common in many military weapons. One launcher design has yielded a stable fragment launch of approximately one gram of aluminum at 8.93 km/s velocity. The other design yielded velocities in excess of 10 km/s, but failed to produce a cohesive fragment launch. This work is ongoing, and future plans are given. Author

A89-30882#
CHARACTERIZING THE DAMAGE POTENTIAL OF RICOCHET DEBRIS DUE TO AN OBLIQUE HYPERVELOCITY IMPACT
WILLIAM P. SCHONBERG (Alabama, University, Huntsville) IN: AIAA, ASME, ASCE, AHS, and ASC, Structures, Structural Dynamics and Materials Conference, 30th, Mobile, AL, Apr. 3-5, 1989, Technical Papers. Part 4. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 2180-2185. refs
(AIAA PAPER 89-1410)

All long-duration spacecraft are susceptible to impacts by meteoroids and pieces of orbiting space debris. Such impacts are expected to occur at extremely high speeds and are expected to strike the spacecraft structure at oblique angles. High obliquity impacts have an especially high potential to cause damage to external spacecraft systems because of the extremely large volume of ricochet debris that they produce. It is found that the diameter of the most damaging ricochet debris particle can be as large as 40 percent of the original projectile diameter and can travel at speeds between 24 and 36 percent of the original projectile impact velocity. It is concluded that obliquity effects of high-speed impacts must be considered in the design of any structure exposed to the meteoroid and space debris environment. Author

A89-31882*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
PARTICLE ADHESION TO SURFACES UNDER VACUUM
JACK B. BARENGOLTZ (California Institute of Technology, Jet Propulsion Laboratory, Pasadena) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 26, Mar.-Apr. 1989, p. 103-108. Previously cited in issue 17, p. 2823, Accession no. A88-43765. refs

A89-31915*# Massachusetts Inst. of Tech., Cambridge.
INDUCED EMISSION OF RADIATION FROM A LARGE SPACE-STATION-LIKE STRUCTURE IN THE IONOSPHERE
D. E. HASTINGS and J. WANG (MIT, Cambridge, MA) AIAA Journal (ISSN 0001-1452), vol. 27, April 1989, p. 438-445. refs
(Contract NAG3-695)

Large conducting structures in the ionosphere may have currents flowing through them which close in the ionospheric plasma. These currents can arise either from current leakage from an onboard power distribution system or by being induced by the motional electric field. Associated with these currents will be broadband electromagnetic radiation in the Alfven and lower hybrid bands. The radiation impedance of this electromagnetic radiation is explored for a structure of space-station-like dimensions as a function of the geometry of the structure and the composition of the ionic environment. It is shown that modification of the collecting area of the structure and environment can be used to minimize the radiation impedance. For a space station, the radiated power will at most be of the order of watts, which does not represent a significant power loss. However, the radiation field will give rise to a substantial pollution of the electromagnetic spectrum in the vicinity of the space station. Design choices to minimize this interference are suggested. Author

N89-10916*# California Polytechnic State Univ., San Luis Obispo. Space Systems Space Welding Project.
THE POTENTIAL OF A GAS CAN WITH PAYLOAD G-169
DAVID TAMIR *In* NASA, Goddard Space Flight Center, The 1988 Get Away Special Experimenter's Symposium p 89-96 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 22A

The feasibility of using welding for the construction, expansion and emergency repair of space based structures is discussed and the advantages of gas tungsten arc welding (GTAW) over other welding techniques are briefly examined. The objective and design concept for the G-169 Get Away Special payload are described. The G-169 experiment will allow the comparison of a space GTA welded joint with a terrestrial GTA welded joint with all parameters held constant except for gravitational forces. Specifically, a bead-on-plate weld around the perimeter of a 2 inch diameter stainless steel pipe section will be performed. The use of Learjet microgravity simulation for the G-169 and other Get Away Special experiments is also addressed. M.G.

N89-10932# Los Alamos National Lab., NM.
LABORATORY INVESTIGATIONS OF LOW EARTH ORBIT ENVIRONMENTAL EFFECTS ON SPACECRAFT
JON B. CROSS 1988 16 p Presented at the Uranium and Electricity: the Complete Nuclear Fuel Cycle, Saskatoon, Saskatchewan, 18 Sep. 1988
(Contract W-7405-ENG-36)
(DE88-009135; LA-UR-88-1229; CONF-880943-2) Avail: NTIS HC A03/MF A01

Operations in low earth orbit (100 to 500 km) must take into consideration the highly oxidative character of the environment. Partial pressures in the range of 10 to the 6th - 10 to the 7th torr of atomic oxygen are present which produces extensive oxidation of materials facing the direction of travel (ram direction). The ram oxidation is most severe not only because of the high flux (10 to the 15th O-atoms/s-sq cm) caused by the orbital velocity of the spacecraft but also because of the high collision energy of oxygen atoms with the ram surfaces (translational energy equivalent to approximately 60,000 K). Ground based simulation of these conditions has been accomplished using a CW laser sustained discharge source for the production of 1 to 5 eV beam of O-atoms with a flux of up to 10 to the 17th O-atoms/s-sq cm. The reactions of atomic oxygen with kapton, Teflon, silver, and various coatings have been studied. The oxidation of kapton has an activation energy of 2.3 Kcal/mole over the temperature range of 25 C to 100 C at a beam energy of 1.5 eV and produces low molecular weight gas phase reaction products (H2O, NO, CO2). Teflon reacts with approximately 0.1 to 0.2 efficiency to that of kapton at 25 C and both surfaces show a rug like texture after exposure to the O-atom beam. Angular scattering distribution measurements of O-atoms show a near cosine distribution from reactive surfaces indicating complete accommodation of the translational energy with the surface while a nonreactive surface (nickel oxide) shows specular like scattering with little accommodation (50 percent) of the translational energy with the surface. A technique for simple on orbit chemical experiments using resistance measurements coated silver strips is described. DOE

N89-10937# Physical Sciences, Inc., Andover, MA.
THE DETERMINATION OF THE SPACECRAFT CONTAMINATION ENVIRONMENT Final Report, 12 Sep. 1983 - 28 Feb. 1987
B. D. GREEN, W. T. RAWLINS, G. E. CALEDONIA, W. J. MARINELLI, and C. WHITE Oct. 1987 384 p
(Contract F19628-83-C-0139)
(AD-A196435; PSI-9139/TR-728; AFGL-TR-87-0303) Avail: NTIS HC A17/MF A01 CSCL 03/2

This report details our efforts in the determination of the on-orbit environment surrounding spacecraft. The research was performed for the Spacecraft Interactions Branch of the Space Physics Division of the Air Force Geophysics Laboratory. This report includes contributions from our subcontractors EKTRON Applied Imaging and Miranda Laboratories. The multilayer project consisted

of three major tasks: a literature survey, preparation for the data of the Particle Analysis Cameras for Shuttle (PACS), and the analysis of the data to create a model of the orbital particulate environment. During the literature search we discovered that many observations were presented with little or no insight provided. Physical Sciences Inc. (PSI) therefore undertook a critical review of the data in an attempt to reconcile seemingly contractory observations and provide needed understanding of the variety of unexpected processes occurring above spacecraft surfaces in low-earth orbit. We were able to make contributions to the understanding of the neutral molecular contamination cloud; the modifications of the ionic environment; the optical contamination glow; and the earlier observations of particulates. GRA

N89-12589*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THE NASA ATOMIC OXYGEN EFFECTS TEST PROGRAM
BRUCE A. BANKS, SHARON K. RUTLEDGE, and JOYCE A. BRADY *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 51-65 1988
Avail: NTIS HC A21/MF A01 CSCL 07/4

The NASA Atomic Oxygen Effects Test Program was established to compare the low earth orbital simulation characteristics of existing atomic oxygen test facilities and utilize the collective data from a multitude of simulation facilities to promote understanding of mechanisms and erosion yield dependence upon energy, flux, metastables, charge, and environmental species. Four materials chosen for this evaluation include Kapton HN polyimide, FEP Teflon, polyethylene, and graphite single crystals. The conditions and results of atomic oxygen exposure of these materials is reported by the participating organizations and then assembled to identify degrees of dependency of erosion yields that may not be observable from any single atomic oxygen low earth orbital simulation facility. To date, the program includes 30 test facilities. Characteristics of the participating test facilities and results to date are reported. Author

N89-12591*# Toronto Univ., Downsview (Ontario). Inst. for Aerospace Studies.
ATOMIC OXYGEN STUDIES ON POLYMERS
W. D. MORISON, R. C. TENNYSON, J. B. FRENCH, T. BRAITHWAITE, M. MOISAN, and J. HUBERT (Montreal Univ., Quebec) *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 89-109 1988
(Contract N60921-86-C-A226; AUSPI-86-207; TP2-325)
Avail: NTIS HC A21/MF A01 CSCL 11/3

The purpose was to study the effects of atomic oxygen on the erosion of polymer based materials. The development of an atomic oxygen neutral beam facility using a SURFATRON surface wave launcher that can produce beam energies between 2 and 3 eV at flux levels as high as approx. 10 to the 17th power atoms/cm (2)-sec is described. Thin film dielectric materials were studied to determine recession rates and and reaction efficiencies as a function of incident beam energy and fluence. Accelerated testing was also accomplished and the values of reaction efficiency compared to available space flight data. Electron microscope photomicrographs of the samples' surface morphology were compared to flight test specimens. Author

N89-12592*# McDonnell-Douglas Astronautics Co., Huntington Beach, CA.
ATOMIC OXYGEN EFFECTS ON CANDIDATE COATINGS FOR LONG-TERM SPACECRAFT IN LOW EARTH ORBIT
E. H. LAN, CHARLES A. SMITH, and J. B. CROSS (Los Alamos National Lab., N. Mex.) *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 110-121 1988
Avail: NTIS HC A21/MF A01 CSCL 22/2

Candidate atomic oxygen protective coatings for long-term low Earth orbit (LEO) spacecraft were evaluated using the Los Alamos National Laboratory O-atom exposure facility. The coatings studied include Teflon, Al2O3, SiO2, and SWS-V-10, a silicon material. Preliminary results indicate that sputtered PTFE Teflon (0.1 micrometers) has a fluence lifetime of 10 to the 19th power O-atoms/cm (2), and sputtered silicon dioxide (0.1 micrometers), aluminum oxide (0.1 micrometers), and SWS-V-10, a silicone, (4 micrometers) have fluence lifetimes of 10 to the 20th power to 10 to the 21st power O-atoms/cm (2). There are large variations in fluence lifetime data for these coatings. Author

N89-12607*# Boeing Aerospace Co., Seattle, WA.
SIMULATION OF THE EFFECTS OF THE ORBITAL DEBRIS ENVIRONMENT ON SPACECRAFT Abstract Only
MICHAEL D. BJORKMAN *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 311 1988
Avail: NTIS HC A21/MF A01 CSCL 22/2

A remedy for the lack of a technique for testing the effects of orbital debris impacts has been sought along two paths at Boeing and elsewhere, firstly through the development of new launcher techniques capable of impact velocities between 8 and 16 km/s and secondly through the development of similitude techniques for modeling 8 to 16 km/s impacts using the present capabilities of projectile launchers. These two approaches are briefly discussed. Author

N89-14331*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
ATOMIC OXYGEN EFFECTS MEASUREMENTS FOR SHUTTLE MISSIONS STS-8 AND 41-G
JAMES T. VISENTINE, comp. Sep. 1988 94 p
(NASA-TM-100459-VOL-1; NAS 1.15:100459-VOL-1) Avail: NTIS HC A05/MF A01 CSCL 07/4

The effects of atomic oxygen exposure upon typical spacecraft materials, such as polyimide films, thermal control paints, epoxies, silicones, and fluorocarbons are summarized. B.G.

N89-14332*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
ATOMIC OXYGEN EFFECTS MEASUREMENTS FOR SHUTTLE MISSIONS STS-8 AND 41-G
JAMES T. VISENTINE, comp. Sep. 1988 90 p
(NASA-TM-100459-VOL-2; NAS 1.15:100459-VOL-2) Avail: NTIS HC A05/MF A01 CSCL 07/4

The effects of the atomic oxygen interactions upon optical coatings, thin metallized films, and advanced spacecraft materials, such as high temperature coatings for infrared optical systems are summarized. Also included is a description of a generic model proposed by JPL, which may explain the atomic oxygen interaction mechanisms that lead to surface recession and weight loss. B.G.

N89-14921*# College of William and Mary, Williamsburg, VA. Dept. of Chemistry.
THE EFFECTS OF ATOMIC OXYGEN ON POLYMERIC MATERIALS Abstract Only
ROBERT A. ORWOLL *In* Hampton Inst., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1988 p 88-89 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 11/3

At the altitudes of low-earth orbit (LEO), atomic oxygen (AO) is the most abundant chemical species. This strong oxidizing agent reacts with virtually any organic material that is not already fully oxidized. Erosion by AO can be extensive and jeopardizes any protective coatings, thermal blankets, adhesives, and structural composites exposed on the exterior of satellites in LEO. Researchers prepared and tested organic materials for their susceptibility to AO using a commercial plasma asher which approximately simulates the oxygen effects in LEO. Experiments were performed on a polyimide, a polysulfone, and two epoxy adhesives into which low molecular-weight additives have been dissolved. Incorporated in the molecular structure of these additives are elements such as silicon whose nonvolatile oxides, which are

formed on exposure to AO, remain as a coating on the surface to create a barrier between the remainder of the organic material and the AO. We find that the additives protect the materials, but the low solubility of some limit their utility. Concurrent studies are underway to measure the effect of the additives on the thermal expansion coefficients of the materials. Tows of aramid fibers, which are important components in the proposed tether satellite systems, have been eroded in the asher. The results which show that the square root of the mass remaining decreases linearly with the time of exposure (see the figure) are consistent with a constant rate of surface erosion. The tensile strength of these eroded tows decreases with time of exposure also; additional measurements are in progress. Author

N89-15005*# California Inst. of Tech., Pasadena. Seismological Lab.

A PLANETARY ULTRA HYPERVELOCITY IMPACT MECHANICS AND SHOCK WAVE SCIENCE FACILITY Abstract Only

THOMAS J. AHRENS *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 3 p Nov. 1987 Previously announced as N86-27141
Avail: NTIS HC A09/MF A01 CSCL 03/2

Using the concept of intercepting orbits from a pair of Space Station serviced free flyers, a class of impact and shock wave experiments pertinent to planetary science can be performed. One proposed free flying vehicle is an impactor dispensor, and the second is the impact laboratory. How collision is achieved by utilizing essentially twice orbital velocity is demonstrated. The impactor dispensor contains a series of small flyer plates or other projectiles which are launched into the trajectory of the impactor laboratory at appropriate positions. The impactor laboratory is a large impact tank similar to those in terrestrial gun laboratories, except that it contains a supply of targets and instrumentation such as high speed cameras, flash X-ray apparatus, and digital recorders. Shock and isentropic pressures of up to 20 Mbar are achievable with such a system which provides 15 km/sec impact velocities for precisely oriented projectiles. B.G.

N89-15009*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

LOW-GRAVITY IMPACT EXPERIMENTS: PROGRESS TOWARD A FACILITY DEFINITION

MARK J. CINTALA *In its* Experiments in Planetary and Related Sciences and the Space Station 3 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 22/1

Innumerable efforts were made to understand the cratering process and its ramifications in terms of planetary observations, during which the experiments both were devoted in many cases to unraveling the contribution of gravitational acceleration to cratering mechanisms. Included among these are the explosion experiments in low-gravity aircraft, the drop-platform experiments, and the high-g centrifuge experiments. Considerable insight into the effects of gravity, among other factors, was gained. Even so, other avenues of investigation were out of reach to workers confined to the terrestrial laboratory. It is in this light that the Space Station is being examined as a vehicle with the potential to support otherwise impractical impact experiments. The results of studies performed by members of the planetary cratering community are summarized; their names and affiliations are listed. Author

N89-15010*# Chicago Univ., IL. Dept. of Physics.

COSMIC DUST COLLECTION WITH A SUB SATELLITE TETHERED TO A SPACE STATION

GEORGE J. CORSO *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 2 p Nov. 1987 Previously announced as N86-27146
Prepared in cooperation with Northwestern Univ., Evanston, IL
Avail: NTIS HC A09/MF A01 CSCL 03/2

The number concentration and density of 1 micron and submicron sized grains in interplanetary space, as well as their relation to the larger zodical dust particles, and the importance of the beta meteoroid phenomenon are currently being questioned. The best approach to collecting large numbers of intact micron and submicron sized cosmic dust particles in real time while avoiding terrestrial and man made contamination would be to employ a tethered subsatellite from a space station down into the earth's atmosphere. Such a subsatellite tied to the space shuttle by a 100 km long tether is being developed. It is also possible that a permanent space station would allow the use of a tether even longer than 100 km. It should be noted that the same tethered collectors could also be employed to study the composition and flux of man made earth orbiting debris in any direction within 100 km or so of the space station. B.G.

N89-15013*# Rice Univ., Houston, TX. Dept. of Space Physics and Astronomy.

THE ORBIT PROPERTIES OF COLLIDING CO-ORBITING BODIES

JOHN W. FREEMAN *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 3 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 03/2

It is generally assumed that an ensemble of small bodies located in similar Keplarian orbits will, because of collisions, tend to disperse into more and more dissimilar orbits. This theory was challenged. Alfven maintains that for the case where the time between collisions is longer than the orbit period and the collisions are essentially inelastic the orbits and velocities will become more similar. This gives rise to the concepts of negative diffusion and jet streams. It is proposed that this question might be investigated experimentally using the space station. The proposed experiment is briefly described. Author

N89-15015*# National Oceanic and Atmospheric Administration, Boulder, CO.

SMALL LINEAR WIND TUNNEL SALTATION EXPERIMENTS: SOME EXPERIENCES

D. A. GILLETTE and P. R. OWEN (Imperial Coll. of Science and Technology, London, England) *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 2 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 14/2

Since the wind tunnel proposed to be used for the Space Station Planetology Experiments are of a rather limited size, some experience and techniques used for saltation experiments in a small linear wind tunnel may be of interest. Three experiences are presented. The first concerns a length effect of saltation mass flux in which the size of the wind tunnel exaggerates the physical process taking place. A second experience concerns a non-optical technique that does not interfere with flow and by which momentum and mass fluxes to the flow may be measured. The technique may also be used to calculate saltation flux. The third experience concerns the use of the momentum equation to estimate momentum fluxes by differences. Author

N89-15021*# Arizona State Univ., Tempe.

DESIGN AND CALIBRATION OF THE CAROUSEL WIND TUNNEL Abstract Only

R. N. LEACH, RONALD GREELEY, JAMES D. IVERSEN, BRUCE R. WHITE (California Univ., Davis.), and JOHN R. MARSHALL *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 2 p Nov. 1987 Previously announced as N86-27154
Avail: NTIS HC A09/MF A01 CSCL 14/2

In the study of planetary aeolian processes the effect of gravity is not readily modeled. Gravity appears in the equations of particle motion along with interparticle forces but the two terms are not separable. A wind tunnel that would permit variable gravity would allow separation of the forces and aid greatly in understanding planetary aeolian processes. The design of the Carousel Wind Tunnel (CWT) allows for a long flow distance in a small sized tunnel since the test section is a continuous circuit and allows for a variable pseudo-gravity. A prototype design was built and

calibrated to gain some understanding of the characteristics of the design and the results presented. B.G.

N89-15025*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX. Dept. of Geology.
KINETICS IN A TURBULENT NEBULAR CLOUD
IAN D. R. MACKINNON (New Mexico Univ., Albuquerque.) and F. J. M. RIETMEIJER *In its* Experiments in Planetary and Related Sciences and the Space Station 3 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 03/2

Model calculations, which include the effects of turbulence during subsequent solar nebula evolution after the collapse of a cool interstellar cloud, can reconcile some of the apparent differences between physical parameters obtained from theory and the cosmochemical record. Two important aspects of turbulence in a protoplanetary cloud include the growth and transport of solid grains. While the physical effects of the process can be calculated and compared with the probable remains of the nebula formulation period, the more subtle effects on primitive grains and their survival in the cosmochemical record cannot be readily evaluated. The environment offered by the Space Station (or Space Shuttle) experimental facility can provide the vacuum and low gravity conditions for sufficiently long time periods required for experimental verification of these cosmochemical models. Author

N89-15027*# Arizona State Univ., Tempe. Dept. of Geology.
ELECTROSTATIC AGGREGATION OF FINELY-COMMINUTED GEOLOGICAL MATERIALS
JOHN R. MARSHALL and RONALD GREELEY *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 2 p Nov. 1987 Previously announced as N86-27156
Avail: NTIS HC A09/MF A01 CSCL 08/7

Electrostatic forces are known to have a significant effect on the behavior of finely comminuted particulate material: perhaps the most prevalent expression of this being electrostatic aggregation of particles into relatively coherent clumps. However, the precise role of electrostatic attraction and repulsion in determining the behavior of geological materials (such as volcanic ash and aeolian dust) is poorly understood. Electrostatic aggregation of fine particles is difficult to study on earth either in the geological or laboratory environment principally because the material in an aggregated state remains airborne for such a short period of time. Experiments conducted in the NASA/JSC - KC135 aircraft are discussed. The aircraft experiments are seen as precursors to more elaborate and scientifically more comprehensive Shuttle or Space Station activities. B.G.

N89-15033*# Brown Univ., Providence, RI. Dept. of Geological Sciences.
DEBRIS-CLOUD COLLISIONS: ACCRETION STUDIES IN THE SPACE STATION
PETER H. SCHULTZ and D. E. GAULT (Murphys Center of Planetology, CA.) *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 2 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 03/2

The growth of planetesimals in the Solar System reflects the success of collisional aggregation over disruption. It is widely assumed that aggregation must represent relatively low encounter velocities between two particles in order to avoid both disruption and high-ejecta velocities. Such an assumption is supported by impact experiments and theory. Experiments involving particle-particle impacts, however, may be pertinent to only one type of collisional process in the early Solar System. Most models envision a complex protoplanetary nebular setting involving gas and dust. Consequently, collisions between clouds of dust or solids and dust may be a more relistic picture of protoplanetary accretion. Recent experiments performed at the NASA-Ames Vertical Gun Range have produced debris clouds impacting particulate targets with velocities ranging from 100 m/s to 6 km/s. The experiments produced several intriguing results that not only warrant further study but also may encourage experiments with the impact conditions permitted in a microgravity environment. Possible Space Station experiments are briefly discussed. Author

N89-15034*# Brown Univ., Providence, RI. Dept. of Geological Sciences.
IMPACTS OF FREE-FLOATING OBJECTS: UNIQUE SPACE STATION EXPERIMENTS
PETER H. SCHULTZ and D. E. GAULT (Murphys Center of Planetology, CA.) *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 2 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 03/2

The transfer of momentum and kinetic energy between planetary bodies forms the basis for wide-ranging problems in planetary science ranging from the collective long-term effects of minor perturbations to the catastrophic singular effect of a major collision. In the former case, the evolution of asteroid spin rates and orientations and planetary rotation rates are cited. In the latter case, the catastrophic angular momenta and the near-global disruption of partially molten planets are included. Although the collisional transfer of momentum and energy were discussed over the last two decades, major issues remain that largely reflect current limitations in earth-based experimental conditions and 3-D numerical codes. Two examples with potential applications in a Space Station laboratory are presented. Author

N89-15039*# California Univ., Davis.
AEOLIAN PROCESSES ABOARD A SPACE STATION: SALTATION AND PARTICLE TRAJECTORY ANALYSIS
BRUCE R. WHITE, RONALD GREELEY, JAMES D. IVERSEN, and R. N. LEACH (Santa Clara Univ., Calif.) *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 3 p Nov. 1987 Previously announced a N86-27165
Avail: NTIS HC A09/MF A01 CSCL 14/2

The Carousel Wind Tunnel (CWT) proposed to study aeolian processes aboard a Space Station consists of two concentric rotating drums. The space between the two drums comprises the wind tunnel section. Differential rates of rotation of the two drums would provide a wind velocity with respect to either drum surface. Preliminary results of measured velocity profiles made in a CWT prototype indicate that the wall bounded boundary layer profiles are suitable to simuate flat plate turbulent boundary layer flow. The two dimensional flate plate Cartesian coordinate equations of motion of a particle moving through the air are explained. In order to assess the suitability of CWT in the analysis of the trajectories of windblown particles, a series of calculations were conducted comparing cases for gravity with those of zero gravity. Results from the calculations demonstrate that a wind tunnel of the carousel design could be fabricated to operate in a space station environment and that experiments could be conducted which would yield significant results contributing to the understanding of the physics of particle dynamics. B.G.

N89-15040*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
A SYSTEM FOR CONDUCTING IGNEOUS PETROLOGY EXPERIMENTS UNDER CONTROLLED REDOX CONDITIONS IN REDUCED GRAVITY
RICHARD J. WILLIAMS *In its* Experiments in Planetary and Related Sciences and the Space Station 4 p Nov. 1987 Previously announced as N86-27166
Avail: NTIS HC A09/MF A01 CSCL 22/1

The Space Shuttle and the planned Space Station will permit experimentation under conditions of reduced gravitational acceleration offering experimental petrologists the opportunity to study crystal growth, element distribution, and phase chemistry. In particular the confounding effects of macro and micro scale buoyancy-induced convection and crystal settling or flotation can be greatly reduced over those observed in experiments in the terrestrial laboratory. Also, for experiments in which detailed

replication of the environment is important, the access to reduced gravity will permit a more complete simulation of processes that may have occurred on asteroids or in free space. A technique that was developed to control, measure, and manipulate oxygen fugacities with small quantities of gas which are recirculated over the sample. This system could be adaptable to reduced gravity space experiments requiring redox control. B.G.

N89-15041*# San Jose State Univ., CA.
NEW TECHNIQUES FOR THE DETECTION AND CAPTURE OF MICROMETEOROIDS Abstract Only
J. H. WOLFE *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 1 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 03/2

In order to understand the origin and distribution of the biogenic elements and their compounds in the solar system, it will be necessary to study materials from many classes of objects. Chemical, elemental, and isotopic measurements of returned samples of comets, asteroids, and possibly extra-solar system dust clouds would provide information on a particularly important class: primitive objects. Extraterrestrial micron-sized particles in the vicinity of Earth are one source of such materials that might otherwise be inaccessible. The Space Station appears to be an eminently suitable platform from which to collect and detect these various particles. The primary challenge, however, is to collect intact, uncontaminated particles which will be encountered at tens of kilometers per seconds. A concept for a micrometeoroid detector that could be deployed from the Space Station was developed which uses a large area detector plate implanted with acoustic transducers. When an impact event occurs, the resulting signal is subjected to spectral analysis providing positive detection, momentum information, and angle of incidence. The primary advantage of this detector is the large area which increases the probability of measuring events. A concept of a nondestuctive micrometeoroid collector for use from a Space Station was also developed. The collector utilizes input port charging of the incoming particle followed by staged high voltage deceleration for nondestructive capture. Low velocity particles (local contamination) would be rejected due to insufficient energy and only uncontaminated micrometeoroids would be collected. Author

N89-15255*# College of William and Mary, Williamsburg, VA. Dept. of Chemistry.
SPACE ENVIRONMENTAL EFFECTS ON POLYMERIC MATERIALS Final Technicaal Report, 1 Jun. 1987 - 15 Jun. 1988
RICHARD L. KIEFER and ROBERT A. ORWOLL 1988 24 p (Contract NAG1-678)
(NASA-CR-184648; NAS 1.26:184648) Avail: NTIS HC A03/MF A01 CSCL 11/2

Two of the major environmental hazards in the Geosynchronous Earth Orbit (GEO) are energetic charged particles and ultraviolet radiation. The charged particles, electrons and protons, range in energy from 0.1 to 4 MeV and each have a flux of 10 to the 8th sq cm/sec. Over a 30 year lifetime, materials in the GEO will have an absorbed dose from this radiation of 10 to the 10th rads. The ultraviolet radiation comes uninhibited from the sun with an irradiance of 1.4 kw/sq m. Radiation is known to initiate chain sission and crosslinking in polymeric materials, both of which affect their structural properties. The 30-year dose level from the combined radiation in the GEO exceeds the threshold for measurable damage in most polymer systems studied. Of further concern is possible synergistic effects from the simultaneous irradiation with charged particles and ultraviolet radiation. Most studies on radiation effects on polymeric materials use either electrons or ultraviolet radiation alone, or in a sequential combination. Author

N89-15414*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
WEAR CONSIDERATION IN GEAR DESIGN FOR SPACE APPLICATIONS
LEE S. AKIN (California State Univ., Long Beach.) and DENNIS P. TOWNSEND 1989 8 p Prepared for presentation at the 5th International Power Transmission and Gearing Conference, Chicao, IL, 25-27 Apr. 1989; sponsored by ASME
(Contract NAG3-20; DA PROJ. 1L1-62209-A-47-A)
(NASA-TM-101457; E-4532; NAS 1.15:101457; AVSCOM-TR-88-C-033; AD-A205575) Avail: NTIS HC A02/MF A01 CSCL 13/9

A procedure is described that was developed for evaluating the wear in a set of gears in mesh under high load and low rotational speed. The method can be used for any low-speed gear application, with nearly negligible oil film thickness, and is especially useful in space stepping mechanism applications where determination of pointing error due to wear is important, such as in long life sensor antenna drives. A method is developed for total wear depth at the ends of the line of action using a very simple formula with the slide to roll ratio V sub s/V sub r. A method is also developed that uses the wear results to calculate the transmission error also known as pointing error of a gear mesh. Author

N89-15572*# Oxford Univ. (England).
OBJECT ORIENTED STUDIES INTO ARTIFICIAL SPACE DEBRIS
J. M. ADAMSON and G. MARSHALL *In* NASA, Marshall Space Flight Center, Fourth Conference on Artificial Intelligence for Space Applications p 163-171 Oct. 1988 Prepared in cooperation with Marshall (G.), Eastleigh (England)
Avail: NTIS HC A21/MF A01 CSCL 09/2

A prototype simulation is being developed under contract to the Royal Aerospace Establishment (RAE), Farnborough, England, to assist in the discrimination of artificial space objects/debris. The methodology undertaken has been to link Object Oriented programming, intelligent knowledge based system (IKBS) techniques and advanced computer technology with numeric analysis to provide a graphical, symbolic simulation. The objective is to provide an additional layer of understanding on top of conventional classification methods. Use is being made of object and rule based knowledge representation, multiple reasoning, truth maintenance and uncertainty. Software tools being used include Knowledge Engineering Environment (KEE) and SymTactics for knowledge representation. Hooks are being developed within the SymTactics framework to incorporate mathematical models describing orbital motion and fragmentation. Penetration and structural analysis can also be incorporated. SymTactics is an Object Oriented discrete event simulation tool built as a domain specific extension to the KEE environment. The tool provides facilities for building, debugging and monitoring dynamic (military) simulations. Author

N89-15792*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
ENVIRONMENTAL MONITORING FOR SPACE STATION WP01
J. M. ZWIENER *In its* Space Station Induced Monitoring p 5-12 Nov. 1988
Avail: NTIS HC A05/MF A01 CSCL 22/2

External contamination monitoring instrumentation for the Space Station work package one (WP01) elements, were imposed on the contractor as deliverable hardware. The monitoring instrumentation proposed by the WP01 contractor in response to the contract requirement includes both real time measurements and passive samples. Real time measurement instrumentation consists of quartz crystal microbalances for molecular deposition, ion gaseous species identification. Internal environmental contamination monitoring for particulates is included in both Lab and HAB modules. Passive samples consists of four sample mounting plates mounted external to the Space Station modules, two on the U.S. LAB, and two on the HAB module. Author

N89-15793*# TS Infosystems, Lanham, MD.
GSFC CONTAMINATION MONITORS FOR SPACE STATION
P. A. CAROSSO, J. L. TVEEKREM, and J. D. COOPERSMITH

In NASA, Marshall Space Flight Center, Space Station Induced Monitoring p 13-17 Nov. 1988
Avail: NTIS HC A05/MF A01 CSCL 22/2

This paper describes the Work Package 3 activities in the area of neutral contamination monitoring for the Space Station. Goddard Space Flight Center's responsibilities include the development of the Attached Payload Accommodations Equipment (APAE), the Polar Orbiting Platform (POP), and the Flight Telerobotic Servicer (FTS). GSFC will also develop the Customer Servicing Facility (CSF) in Phase 2 of the Space Station. Author

N89-15794*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
PLASMA INTERACTIONS MONITORING SYSTEM
WILLIAM T. ROBERTS *In its* Space Station Induced Monitoring p 19-25 Nov. 1988
Avail: NTIS HC A05/MF A01 CSCL 22/2

The plasma environment around the space station is expected to be different from that environment which occurs naturally at these altitudes because of the unprecedented size of the space station, its orbital motion, and its high power distribution system. Although there are models which predict the environment around the station, they do not take into account changes in configuration, changes in the natural and induced environments, nor interactions between the different environments. There will be unique perturbations associated with the space station, which will vary as the space station is being developed. Even after the developed space station has been completed environmental conditions will change as the payloads are changed and as the station systems and materials undergo degradation and modification. Because the space station will be a point of many varied activities the environment will continually undergo perturbations from effluents resulting from operations of the reboost module, EVA, airlock operations, and vacuum venting. The use of the Mobile Service Center will cause disturbances which cannot, at this time, be predicted. Also, the natural environment will be affected by solar flares. In addition, the operations of attached payloads, (e.g., ASTROMAG) themselves will undoubtedly cause perturbations to the ambient environment. Finally, the natural environment will change as a result of natural perturbations such as solar flares and geomagnetic storms. Author

N89-15795*# Michigan Univ., Ann Arbor. Dept. of Atmospheric and Oceanic Science.
THE SPACE STATION NEUTRAL GAS ENVIRONMENT AND THE CONCOMITANT REQUIREMENTS FOR MONITORING
GEORGE CARIGNAN *In* NASA, Marshall Space Flight Center, Space Station Induced Monitoring p 27-28 Nov. 1988
Avail: NTIS HC A05/MF A01 CSCL 22/2

At 340 km, for typical conditions, the neutral atmospheric density is several times 10E8/cc and is thus more abundant than the ionized component by several factors of 10. At that altitude, the principal series is atomic oxygen with 10 percent N2, and 1 percent He, and trace amounts of O2, H, N, NO, and Ar. The constituent densities are highly variable with local time, latitude, and geophysical indices. The physical interaction with surfaces at orbital velocity leads to large buildup of density on forward faces and great depletions in the wakes of objects. Chemical reactions lead to major modifications in constituent densities as in the case of the conversion of most colliding oxygen atoms to oxygen bearing molecules. The neutral environment about an orbiting body is thus a complex product of many variables even without a source of neutral contaminants. The addition of fluxes of gases emanating from the orbiting vehicle, as will be the case for the Space Station, with the associated physical and chemical interactions adds another level of complexity to the character of the environment and mandates a sophisticated measurement capability if the neutral environment is to be quantitatively characterized. Author

N89-15796*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
A COMPACT IMAGING SPECTROMETER FOR STUDIES OF SPACE VEHICLE INDUCED ENVIRONMENT EMISSIONS
MARSHA R. TORR, ed. and D. G. TORR (Alabama Univ., Huntsville.) *In its* Space Station Induced Monitoring p 31-38 Nov. 1988
Avail: NTIS HC A05/MF A01 CSCL 22/2

On the basis of spectral measurements made from the Space Shuttle and on models of the possible Space Station external environment, it appears likely that, even at the planned altitudes of Space Station, photon emissions will be induced. These emissions will occur to some degree throughout the UV-visible-IR spectrum. The emissions arise from a combination of processes including gas phase collisions between relatively energetic ambient and surface emitted or re-emitted atoms or molecules, where the surface raises some species to excited energy states. At present it is not possible to model these processes or the anticipated intensity levels with accuracy, as a number of fundamental parameters needed for such calculations are still poorly known or unknown. However, it is possible that certain spectral line and band features will exceed the desired goal that contaminant emissions not exceed the natural zodiacal background. However, in the near infrared and infrared, it appears that this level will be exceeded to a significant degree. Therefore it will be necessary to monitor emission levels in the vicinity of Space Station, both in order to establish the levels and to better model the environment. In this note, we briefly describe a small spectrometer that is suitable for monitoring the spectrum from 1200A to less than or approximately 12,000A. This instrument uses focal plane array detectors to image this full spectral range simultaneously. The spectral resolution is 4 to 12A, depending on the portion of the wavelength range. Author

N89-15799*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SPACE STATION SURFACE DEPOSITION MONITORING
E. R. MILLER *In its* Space Station Induced Monitoring p 51-57 Nov. 1988
Avail: NTIS HC A05/MF A01 CSCL 22/2

Quartz crystal microbalance sensors are recommended to verify and monitor surface deposition on the early transverse boom as well as the later dual-keel Space Station configurations. Performance and placement of these sensors are discussed and compared to imposed maximum mass deposition rate requirements at the science instrument and critical power locations. Additional measurements are suggested to gain further knowledge on properties of the deposited material. Author

N89-15800*# Science and Engineering Associates, Inc., Englewood, CO.
CONTAMINATION CONTROL REQUIREMENTS DOCUMENT JSC 30426 RECOMMENDED UPDATES
RAY RANTANEN *In* NASA, Marshall Space Flight Center, Space Station Induced Monitoring p 59-69 Nov. 1988
Avail: NTIS HC A05/MF A01 CSCL 22/2

Contamination control requirements for the Space Station have been evolving over the last few years. Workshops, comments by experimenters and continuing analysis have resulted in recommending changes to the November 19, 1986 version of Space Station External Contamination Control Requirements, JSC 30426. These are summarized and presented, so that the requirements can be revised as soon as possible, to minimize costly design impacts on the Space Station. Author

N89-16447# Air Force Weapons Lab., Kirtland AFB, NM.
METHOD FOR LONG TERM IONIZING RADIATION DAMAGE PREDICTIONS FOR THE SPACE ENVIRONMENT Final Report, Nov. 1982 - Dec. 1987
R. K. MAIER Aug. 1988 108 p
(AD-A199693; AFWL-TR-87-136) Avail: NTIS HC A06/MF A01 CSCL 06/7

The objective of the work is to predict the total dose damage from low level ionizing radiation sources for very long (5 years) exposure times. A prior effort to extrapolate annealing data to long times used linear systems theory or the convolution integral. Problems with the linear systems theory approach are: the damage

is assumed to be linear even though the experimental data show a saturation effect; the annealing function, which is to be combined with the dose rate, needs to be known for a very long length of time (i.e., a 5-year observation of the annealing); and to do the integral numerically using data requires large amounts of computation. GRA

N89-18515*# Naval Academy, Annapolis, MD. Dept. of Aerospace Engineering.
THE SPINNING ARTIFICIAL GRAVITY ENVIRONMENT: A DESIGN PROJECT
ROBERT PIGNATARO, JEFF CRYMES, TOM MARZEC, JOE SEIBERT, and GARY WALKER 27 Apr. 1987 159 p
(Contract NGT-21-002-080)
(NASA-CR-184757; NAS 1.26:184757) Avail: NTIS HC A08/MF A01 CSCL 22/2

The SAGE, or Spinning Artificial Gravity Environment, design was carried out to develop an artificial gravity space station which could be used as a platform for the performance of medical research to determine the benefits of various, fractional gravity levels for astronauts normally subject to zero gravity. Desirable both for its medical research mission and a mission for the study of closed loop life-support and other factors in prolonged space flight, SAGE was designed as a low Earth orbiting, solar powered, manned space station. Author

N89-18521# Rockwell International Corp., Seal Beach, CA. Satellite and Space Electronics Div.
ENVIRONMENTAL EFFECTS ON SPACECRAFT MATERIAL
J. W. HAFFNER, R. J. DEMPSEY, D. E. ANDERSON, and J. G. KELLEY May 1988 60 p
(Contract F19628-88-C-0008)
(AD-A202112; AFGL-TR-88-0128; SR-1) Avail: NTIS HC A04/MF A01 CSCL 22/2

A study of the present state of knowledge concerning the effects of the natural environments on spacecraft materials has been carried out. The study consisted of a literature review, a questionnaire mailing, and some follow-up facility visits. This is the report describing that study and the conclusions reached. At the present time, the effects due to single components of the space environment (radiations, plasmas, gases, particles, fields, etc.) are either well understood or are actively being investigated. Among the most active areas are atomic oxygen effects (erosion and glow), hot plasma charging, space debris object punctures, and nuclear radiation degradation of exposed materials. Some synergistic effects are also being studied. GRA

N89-18603# Aerospace Corp., El Segundo, CA. Space Sciences Lab.
EFFECTS OF HEAVY IONS ON MICROCIRCUITS IN SPACE: RECENTLY INVESTIGATED UPSET MECHANISMS
ROKUTARO KOGA and WOJCIECH A. KOLASINSKI 15 Oct. 1988 37 p
(Contract F04701-85-C-0086)
(AD-A201711; TR-0086(6940-05)-21; SD-TR-88-91) Avail: NTIS HC A03/MF A01 CSCL 09/1

Upset of microcircuits in space have been attributed to heavy ions. In recent studies of the failure mechanisms, we have employed a wide range of test methods. These studies and the application of the test results to space-borne microcircuits are presented. GRA

N89-19106# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Inst. fuer Raumsimulation.
PHYSICAL CONDITIONS FOR SPACE FLIGHT EXPERIMENTS [PHYSIKALISCHE BEDINGUNGEN DES EXPERIMENTIERENS IM WELTRAUM]
H. HAMACHER *In its* Second Summer School on Microgravity. 2: Life Sciences as Main Subject p 35-59 Jun. 1988 In GERMAN
Avail: NTIS HC A09/MF A01

Orbital flight is considered for the study of weightlessness simulation. Microgravitational yield is analyzed, including perturbing forces and effects, external forces, tidal effects, rotation, internal forces, and acceleration at the experiment place. Sensitivity of experiments to residual accelerations is outlined. ESA

N89-19327# Air Force Geophysics Lab., Hanscom AFB, MA.
MEASUREMENTS OF SHUTTLE GLOW ON MISSION STS 41-G
W. F. DENIG, S. B. MENDE, G. R. SWENSON, D. J. KENDALL, R. L. GATTINGER, and E. J. LLEWELLYN (Saskatchewan Univ., Saskatoon.) 29 Sep. 1988 14 p
(AD-A201769; AFGL-TR-88-0262) Avail: NTIS HC A03/MF A01 CSCL 22/1

The analysis of data from a set of experiments conducted during Mission STS 41-G has shown that the intensity of the shuttle glow measured during this mission was more than an order of magnitude less than the intensity measured under similar conditions on earlier flights. In addition the thruster enhanced glow was found to be spectrally continuous at the 0.4 nm resolution of the optical systems. Two separate activities, namely the Canadian Orbiter Glow (OGLOW) experiment and the USAF Auroral Photography Experiment (APE), were conducted simultaneously during STS 41-G and resulted in similar findings. The goals of both the OGLOW and the APE were to image earth aurora and airglow as well as glows emanating off shuttle surfaces. The experimental apparatus used for each experiment was a separate, hand-held, image intensified camera system with appropriate front-end optics. The interferometry data reported here were obtained using Fabry Perot techniques. GRA

N89-19354# Hughes Research Labs., Malibu, CA.
FLIGHT MODEL DISCHARGE SYSTEM Report, Mar. 1987 - Apr. 1988
R. R. ROBSON and W. W. WILLIAMSON Jun. 1988 85 p
(Contract F19628-83-C-0143)
(AD-A201605; HAC-REF-F4890; AFGL-TR-88-0150; SR-4) Avail: NTIS HC A05/MF A01 CSCL 22/1

The Flight Model Discharge System (FMDS) Program has completed its fourth year. The FMDS is a spacecraft charge control system designed to overcome the problem of charge buildup on a space vehicle which occurs during periods of adverse space environmental conditions. An overview of the FMDS system is presented, followed by an in-depth treatment of the significant technical developments that have occurred during the past year. The major areas covered include the plasma generator and electrostatic analyzer testing. GRA

N89-19760# McDonnell-Douglas Astronautics Co., Huntsville, AL.
ELECTRIC FIELDS IN EARTH ORBITAL SPACE Annual Report, Sep. 1987 - Sep. 1988
W. P. OLSON and K. A. PFITZER 19 Oct. 1988 26 p
(Contract N00014-80-C-0796; RR02101)
(AD-A201747) Avail: NTIS HC A03/MF A01 CSCL 04/1

A model of the ground state magnetosphere was developed previously and it is suggested that the basic magnetosphere is formed and maintained simply by the interaction of the solar wind with the geomagnetic field. It is known, however, that the magnetosphere responds dynamically to changes in the interplanetary magnetic field (IMF). Instead of the qualitative reconnection theory (which we believe is basically incorrect), we have examined this response in terms of electromagnetic wave propagation in the interplanetary region. We suggest that the interplanetary plasma (solar wind) is magnetized by solar magnetic sector structure. Electromagnetic waves of higher frequency can propagate through the solar wind without appreciable attenuation. It is the interaction of these disturbance waves with the magnetosphere that causes the observed magnetospheric response to the IMF. The propagation of electromagnetic disturbances in the interplanetary region and their interaction with the magnetosphere are examined. Only certain modes propagate and there are further restrictions on the wave at the magnetopause. Southward and northward disturbances enter the magnetotail and then propagate within the magnetosphere. A magnetic field model

is developed that includes propagating waves within the magnetosphere. These models will help us develop a quantitative model of magnetospheric tail dynamics. GRA

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INTERNATIONAL

Includes descriptions, interfaces and requirements of international payload systems, subsystems and modules considered part of the Space Station system and other international Space Station activities such as the Soviet Salyut.

A89-10484
YEARBOOK 1987 I; DGLR, ANNUAL MEETING, BERLIN, FEDERAL REPUBLIC OF GERMANY, OCT. 5-7, 1987, REPORTS [JAHRBUCH 1987 I; DGLR, JAHRESTAGUNG, BERLIN, FEDERAL REPUBLIC OF GERMANY, OCT. 5-7, 1987, VORTRAEGE]
Meeting sponsored by DGLR. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, 482 p. In German and English. For individual items see A89-10485 to A89-10539.

Technological, political, economic, and historical aspects of aeronautics and astronautics are examined in reviews and reports, with a focus on recent developments in the FRG. Topics addressed include long-term planning within the FRG Planning Framework for High Technology and Space Flight (OHR), satellite systems, orbital systems, space transportation systems, space-flight technology, and microgravity applications. Consideration is given to aerodynamics; configurational design and flight mechanics; flight-control technology; aircraft propulsion; structures, materials, and fabrication techniques; and the history of aviation and rocketry in Germany. T.K.

A89-10489
STRUCTURES, MATERIALS, AND CONSTRUCTION TECHNIQUES FOR FUTURE TRANSPORT AND ORBITAL SYSTEMS [STRUKTUREN, WERKSTOFFE UND BAUWEISEN FUER ZUKUENFTIGE TRANSPORT- UND ORBITALSYSTEME]
H. LUDWIG (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 32-37. In German.
(DGLR PAPER 87-076)

The findings of the FRG Planning Framework for High Technology and Space Flight (OHR) with regard to advanced materials and structures are summarized in a series of outlines, tables, diagrams, and drawings and briefly discussed. For space transportation systems, the major requirements are structural materials capable of withstanding extremely high temperatures (1400 C without thermal protection and 2000 C with a protective layer), passive and active thermal protection systems, modeling studies of aerothermoelastic and dynamic behavior, advanced CFRP and fiber-reinforced ceramic materials for engines, and improved structural test facilities. For orbital systems, long-term studies of temperature and radiation effects, improved assembly and deployment methods, and meteorite protection systems are required. T.K.

A89-10493
SYSTEMS AND OPERATIONAL TECHNOLOGY [SYSTEM- UND EINSATZTECHNIK]
W. SOBOTTA (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 61-66. In German.
(DGLR PAPER 87-097)

The recommendations of the FRG Planning Framework for High Technology and Space Flight (OHR) with respect to systems analysis and operational planning (SA/OP) are reviewed and illustrated with tables and flow charts. The increasing European role in LEO in the era of the International Space Station is discussed; the current status of SA/OP in the FRG is surveyed; and particular attention is given to the critical SA/OP technologies identified in the OHR, including assembly/disassembly, checkout, activation/deactivation, data management, transportation and handling, and servicing and housekeeping. Also considered is the need to coordinate the SA/OP efforts with OHR R&D programs in related fields such as knowledge-based systems, automation and robotics, simulation technology, and advanced communication and data-processing methods. T.K.

A89-10495
HYBRID THERMAL CIRCULATION SYSTEM FOR FUTURE SPACE APPLICATIONS [HYBRID-THERMALKREISLAUF FUER ZUKUENFTIGE RAUMFAHRT-ANWENDUNGEN]
H. G. WULZ, H. KREEB, and W. FLECK (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 72-77. In German.
(DGLR PAPER 87-092)

The design concept and prototype performance of a hybrid two-phase circulation system for temperature control of large spacecraft are reported. The system comprises a mechanically pumped loop for startup and overload conditions and a capillary-pumped loop capable of normal operation, decoupled from the mechanical system, with no consumption of electrical power. The advantages of the hybrid system include high heat-transfer capacity (10-200 kW m, depending on the media and evaporators employed), self-regulation, vibration and shock resistance, heat-load sharing capability, and long-term maintenance-free operation. A model of the capillary-pumped component is currently being tested and has demonstrated transport of 1-2 kW over 10-15 m. T.K.

A89-10497
UTILIZATION OF COLUMBUS BY THE MICROGRAVITY DISCIPLINES - STATUS, PROBLEMS, PERSPECTIVES
R. BACKHAUS, I. EGRY, and J. NEUBERT (DFVLR, Cologne, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 83-87. refs
(DGLR PAPER 87-137)

The findings of an ESA scientific and commercial utilization study for the Columbus program are summarized and discussed, with emphasis on the definition of model payloads and their incorporation in two reference missions (a manned microgravity research mission using the Attached Pressurized Module and a semiautomated microgravity research mission using the Man-Tended Free Flyer). Consideration is given to model payloads in fluid physics, crystal growth, and metallurgy; the manned and semiautomated materials laboratories; general-purpose and dedicated life-sciences facilities; radiation and exobiology experiments on a polar platform; and mass, cost, and scheduling factors affecting utilization. T.K.

A89-10499
THE SAFETY PLAN FOR SPACELAB MISSION D-2 [DAS SICHERHEITSKONZEPT FUER DIE SPACELAB MISSION D-2]
H. SCHUERMANNS (DFVLR, Cologne, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 96-98. In German.
(DGLR PAPER 87-139)

A brief examination of safety issues for manned space missions is given, with a focus on safety planning for the second FRG Spacelab mission D-2. The conditions and regulations prior to the first mission (D-1) are reviewed; a number of specific problems

encountered on D-1 are listed and analyzed; and specific recommendations for D-2 are presented regarding safety procedures, cooperation with NASA, quality control and reliability, payload and crew operations, and documentation. Also included is a more general discussion of recent aerospace, transportation, and industrial accidents involving high technology; here human errors or a lack of management control are cited as dominant causes, and it is concluded that technological and organizational systems should be redesigned to limit the potential damage from human errors. T.K.

A89-10500
EUROPEAN DEVELOPMENT POSSIBILITIES IN THE DIRECTION OF A MANNED SPACE STATION [EUROPAEISCHE ENTWICKLUNGSMOEGLICHKEITEN IN RICHTUNG EINER BEMANNTEN RAUMSTATION]
H. M. BRAUN, H. FRANCOIS, and F. GAMPE (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 99-105. In German.
(DGLR PAPER 87-140)

The ESA Columbus program for participation in the NASA International Space Station is discussed, with a focus on components of for the later development of an independent European Space Station (ESS). The evolution from Columbus to ESS is foreseen as comprising the following stages: (1) an initial step based on the Columbus Man-Tended Free Flyer (MTFF) plus the Hermes manned reusable launch vehicle, (2) an intermittently manned ministation adding a Resource Module to (1), and (3) the full ESS, adding to (2) a second MTFF and an interconnector element. The latter would be developed from the Columbus Pressurized Module and include an escape vehicle, an airlock, a manipulator station, and facilities permitting two spacecraft to be docked in at the same time. Extensive diagrams and drawings are provided. T.K.

A89-10502
STATUS AND DEVELOPMENT OF SOLAR-DYNAMIC POWER SUPPLY SYSTEMS FOR FUTURE SPACE STATIONS [STAND UND ENTWICKLUNG SOLARDYNAMISCHER ENERGIEVERSORGUNGSSYSTEME FUER ZUKUENFTIGE RAUMSTATIONEN]
A. FRITZSCHE and W.-J. DENNER (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 113-121. In German. refs
(DGLR PAPER 87-114)

European efforts to develop solar-dynamic electric-power devices for the orbital infrastructure of the Space Station era and beyond are surveyed. The primary components of a solar-dynamic system are listed and briefly characterized, and the advantages and limitations of Rankine, Stirling, and Brayton systems are discussed. Topics addressed include operational requirements, materials and safety problems, transport and integration considerations, and sensitivity to changes in on-orbit conditions. Diagrams, drawings, and a table listing projected performance data for three different realizations of a reference configuration are provided. T.K.

A89-10503
H2O2-BASED INTEGRATED ENERGY AND MEDIA SUPPLY SYSTEM FOR MANNED SPACE STATIONS [ENERGIE- UND MEDIENVERBUND AUF H2O2-BASIS FUER BEMANNTE RAUMSTATIONEN]
M. FISCHER and B. OBERLE (DFVLR, Institut fuer technische Thermodynamik, Stuttgart, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 122-128. In German. refs
(DGLR PAPER 87-115)

The design concept of an integrated system linking H2/O2 fuel cells for electric-power generation with the environmental and life-support system of a manned space station is presented in extensive diagrams, graphs, and flow charts and discussed. The requirements of planned missions regarding capacity, service life, orbit, eclipse cycles, and complexity are reviewed; the operation of a fuel-cell/electrolyzer energy system is described; and particular attention is given to secondary energy storage during eclipse, adaptation to load profiles, power supply during emergencies or servicing, thermal energy supply, H2/O2 AOCS propulsion, life support, and storage problems. T.K.

A89-10532
FLIGHT LOADING AND ITS EXPERIMENTAL SIMULATION FOR FUTURE SPACECRAFT SYSTEMS [FLUGLASTEN UND IHRE VERSUCHSTECHNISCHE SIMULATION BEI ZUKUENFTIGEN RAUMFAHRTSYSTEMEN]
HUBA ORY (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 384-394. In German. refs
(DGLR PAPER 87-125)

The test and modeling techniques currently used to simulate and predict the quasi-static, dynamic, and thermal loads encountered by spacecraft and payloads during launch, orbital operations, and reentry are examined in an analytical review. Topics addressed include typical mission profiles, the definition of flight loading, flight measurements, the construction of the mathematical model, the computation of dynamic response, structure identification, and the technical implementation of simulation tests. Extensive diagrams, drawings, and graphs of typical test results are provided. T.K.

A89-10534
DYNAMIC SIMULATION, AN INDISPENSABLE TOOL IN THE CONSTRUCTION AND OPERATION OF FUTURE ORBITAL SYSTEMS [DYNAMISCHE SIMULATION, EIN UNVERZICHTBARES WERKZEUG ZUM BAU UND BETRIEB KUENFTIGER ORBITALSYSTEME]
ST. GRAUL (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IN: Yearbook 1987 I; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 406-413. In German.
(DGLR PAPER 87-127)

The implications of the spacecraft and missions planned for the ESA Columbus program on the International Space Station for structural design and analysis are reviewed and illustrated with extensive drawings, graphs, and diagrams. The important differences between previous single-spacecraft missions and the complex multibody systems of the Columbus orbital infrastructure are discussed, and it is pointed out that actual test simulations of large structures on the ground are not feasible. The numerical algorithms used to simulate the nonlinear behavior of large flexible systems are described, and particular attention is given to the major Columbus components, robotics applications, and orbital-capture and docking tasks. T.K.

A89-10716
PHYSICAL/TECHNICAL PRINCIPLES BEHIND THE DEVELOPMENT AND APPLICATION OF SPACECRAFT [FIZIKO/TEKHNICHESKIE OSNOVY SOZDANIIA I PRIMENENIIA KOSMICHESKIKH APPARATOV]
GENNADII PETROVICH DEMENT'EV, ALEKSANDR GRIGOR'EVI ZAKHAROV, and IURII KONSTANTINOVIC KAZAROV Moscow, Izdatel'stvo Mashinostroenie, 1987, 264 p. In Russian. refs

Various aspects of spacecraft design, development, and application are discussed, with some projections made concerning space programs up to the year 2000. Particular consideration is given to the functional design of spacecraft, the structural design and application of orbital complexes, the development of spacecraft with two-mode liquid rocket engines and low-thrust engines, the

features of onboard computers, and advanced spacecraft construction materials. B.J.

A89-10719
PROBLEMS IN SPACE EXPLORATION [PROBLEMY OSVOENIIA KOSMOSA]
SERGEI DMITRIEVICH GRISHIN and SERGEI VASIL'EVICH CHEKALIN Moscow, Izdatel'stvo Znanie (Novoe v Zhizni, Nauke i Tekhnike. Seriia Kosmonavtika, Astronomiia, No. 1), 1988, 64 p. In Russian. refs

Articles are presented on various aspects of the Soviet space program. Particular attention is given to the development of space transportation systems, space energy supplies, construction in weightlessness, in-orbit repair and servicing, and ecological aspects of space exploration. B.J.

A89-11558
COLUMBUS PRESSURIZED MODULES - AERITALIA ROLE IN MANNED SPACE SYSTEMS
E. VALLERANI, L. D'EMILIANO, and D. BOGGIATTO (Aeritalia S.p.A., Gruppo Sistemi Spaziali, Turin, Italy) (IAF, International Astronautical Congress, 38th, Brighton, England, Oct. 10-17, 1987) Acta Astronautica (ISSN 0094-5765), vol. 17, Aug. 1988, p. 769-777.
(IAF PAPER 87-73)

The Columbus Pressurized Modules (PMs), the Attached PM, and the PM-2 are examined. The events and ideas leading up to the formulation of the Columbus concept are reviewed. The Attached PM is planned to be a direct extension of the manned core of the Space Station. The PM-2 and the Resource Module make up the Man Tended Free Flyer. The Attached PM is built to be occupied by 2 crew members, operating systems and payloads, and performing maintenance. The PM-2 would be unattended except for servicing periods every 6 months. The PMs are described and illustrated and their functions in the Space Station are discussed. R.B.

A89-12113#
LEGAL ASPECTS OF INTERNATIONAL COMPETITION IN PROVISION OF LAUNCH SERVICES
STEPHEN E. DOYLE (Aerojet TechSystems Co., Sacramento, CA) IN: Colloquium on the Law of Outer Space, 30th, Brighton, England, Oct. 10-17, 1987, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 203-215. refs

Recent increases in commercialization and competition of launch services are discussed with reference to the international legal framework set up to regulate space activities and assign liability for accidental losses or damage. The specific activities involved in launch services are listed in tables and described; the detailed provisions of the applicable international agreements are summarized; and insurance problems are considered. It is concluded that the current legal status is complex, with the obligations and rights of nations and commercial services defined differently in different treaties and agreements. Although the most consistent and inclusive regulation is provided by the Registration Convention of 1976, only 25 percent of the countries have signed this agreement (as compared with 58 percent for the Space Treaty of 1967). T.K.

A89-12118#
INTERNATIONAL LEGAL ASPECTS OF COMMERCIALIZATION OF PRIVATE ENTERPRISE SPACE ACTIVITIES
GABRIELLA CATALANO SGROSSO (Roma, Universita, Rome, Italy) IN: Colloquium on the Law of Outer Space, 30th, Brighton, England, Oct. 10-17, 1987, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 251-262. refs

The international treaty provisions governing commercial space activities are reviewed, and a number of specific problems involving the utilization of the International Space Station are examined in detail. Consideration is given to pollution control problems; docking and access to Space Station facilities; jurisdiction and control of Space Station activities; national, multinational, and international space station concepts; choice-of-law rules; and bilateral memoranda of understanding governing the Space Station. Particular attention is given to intellectual property rights and patents, ESA-NASA memoranda of understanding, the different types of agreements negotiated between NASA and commercial users (Technical Exchange Agreement, Industrial Guest Investigator, and Joint Endeavor Agreement), the impact of the U.S. Freedom of Information Act and Space Act on international participants, and ESA contract conditions. T.K.

A89-12738
OSCILLATIONS OF A SATELLITE-PROBE TETHERED WITH AN INEXTENSIBLE CABLE IN AN INHOMOGENEOUS ATMOSPHERE [KOLEBANIIA SPUTNIKA-ZONDA, BUKSIRUEMOGO NA NERASTIAZHIMOI NITI V NEODNORODNOI ATMOSFERE]
E. M. SHAKHOV Prikladnaia Matematika i Mekhanika (ISSN 0032-8235), vol. 52, July-Aug. 1988, p. 567-572. In Russian.

The oscillations of a low-mass satellite tethered to an orbital station by a long inextensible cable are considered which arise under the effect of aerodynamic drag and the tightening of the cable in an atmosphere of variable density. For a given satellite drag coefficient, the oscillation period is determined by the atmospheric density at the flight altitude of the orbital station, while the amplitude difference and the semiperiod difference in the case of upward and downward deviations from the relative-equilibrium position are characterized by the atmospheric density gradient. Ways to use the satellite as a probe are considered. B.J.

A89-13700
SPACE RESEARCH AND POLICY IN THE UPCOMING DECADES [LA RECHERCHE ET LA POLITIQUE SPATIALE DANS LES PROCHAINES DECENNIES]
Academie des Sciences (Paris), Comptes Rendus, Serie Generale, La Vie des Sciences (ISSN 0762-0969), vol. 5, no. 2, Mar.-Apr. 1988, p. 111-151. In French.

Developments projected for the upcoming decades in space research and technology are reviewed in order to examine the advantages and problems of manned space flight, unmmanned spacecraft, and man-tended platforms. Developments in the French space program including Ariane V, Hermes, and Columbus are considered. It is shown that the majority of projected space programs (including astronomical, geophysical, meteorological, and earth-observing satellites) are hindered by the presence of man. Man's presence may be useful for microgravity and biology experiments in space, and manned flights are essential for programs such as space medicine, the construction of large structures in space, and the collection of planetary samples. The importance of robotics and expert systems in future space activities is emphasized, and recommendations for the future are proposed. R.R.

A89-14739
DESIGN OF ONBOARD ANTENNAS WITH A LOW SIDELOBE LEVEL [PROEKTIROVANIE BORTOVYKH ANTENN S NIZKIM UROVNEM BOKOVOGO IZLUCHENIIA]
I. A. STRUKOV, D. P. SKULACHEV, and A. N. TKACHEV IN: Scientific instrumentation for space studies. Moscow, Izdatel'stvo Nauka, 1987, p. 94-104. In Russian. refs

The radiation characteristics of millimeter-wave horn antennas with a low sidelobe level are examined, and it is shown that corrugated radiators are superior to the conventional smooth ones. An analysis is made of the radiation characteristics of parabolic horn antennas with corrugated radiators. As an example, attention is given to the design and engineering characteristics of the antenna system for the 8-mm-band radiometer in the spaceborne Relikt-1 experiment, designed to measure the relic radiation. B.J.

A89-15114
SPACE-CABIN ATMOSPHERE AND EVA [ATMOSPHERE D'UNE CABINE SPATIALE ET SORTIE EXTRA-VEHICULAIRE]
H. MAROTTE (Centre d'Essais en Vol, Laboratoire de Medecine Aerospatiale, Bretigny-sur-Orge, France) and M. WEIBEL (Avions

Marcel Dassault-Breguet Aviation, Saint-Cloud, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 131, 1988, p. 4-11. In French. refs

The conditions for aeroembolism formation are reviewed, and preventive measures are discussed with respect to pressure-suit and pressurization-system design. A discrepancy exists between the requirements for space cabin pressurization and EVA. Decompression sickness during EVA can be prevented by either direct denitrogenation or a mixed procedure. The EVA requirements of the Space Station dictate a pressure-suit pressure of 659 hPa, while the requirements of Hermes dictate a pressure of about 400-450 hPa. For the case of an emergency EVA pressure suit, the highest possible pressure is recommended as a means of preventing aeroembolism formation. R.R.

A89-17272
WHAT ARE EUROPEANS LOOKING FOR IN SPACE? AMBITIOUS PROGRAMS - DO THEY JUSTIFY THEIR COSTS? [WAS WOLLEN DIE EUROPAEER IM WELTRAUM? EHRGEIZIGE PROGRAMME - RECHTFERTIGEN SIE DEN EINSATZ?]
REIMAR LUEST (ESA, Paris, France) Astronautik (ISSN 0004-6221), vol. 25, July-Sept. 1988, p. 72-75. In German.

The goals of ESA in space are discussed. The economic reasons driving European space projects are reviewed. The cooperation between different European nations is pointed out. C.D.

A89-17275
CHINA ADVANCES IN SPACE
G. LYNWOOD MAY Spaceflight (ISSN 0038-6340), vol. 30, Nov. 1988, p. 428-433.

The Chinese space industry is examined, focusing on the commercial aspects of the Chinese space program. The Long March expendable launch vehicles are examined, including the vehicle configurations and capabilities, and efforts to market the vehicles. Developments in communications satellites are reviewed, listing Chinese recoverable satellites and discussing the use of these satellites by other countries. Chinese launch sites, environmental test equipment, the supporting space network, and the tracking and control network are considered. R.B.

A89-17628#
EURECA - A COMPLEMENT TO THE MANNED SPACE STATION SYSTEM
J. K. VON DER LIPPE (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 6 p.
(IAF PAPER 88-0005)

The EURECA program is presently in its final phase, the integration of the flight unit system and preparation for its first mission in 1991. This platform will present the first operational retrievable carrier for long-duration missions after the SPAS-01 system for short missions. The concept of this retrievable platform, fully autonomous and dedicated to the assigned mission needs, is an attractive feature to the user, with considerable advantages in comparison with multiuser systems like the Space Station. With these favorable features in mind, the EURECA concept has been further developed for dedicated missions of astrophysics, life science, as well as tethered earth observation application, and an industrial operation is in preparation. Author

A89-17652#
VLD/ERA: A FRENCH EXPERIMENT ON THE SOVIET MIR STATION - AN ATTRACTIVE CHALLENGE IN DESIGN/DEVELOPMENT AND QUALIFICATION
GILLES DEBAS, PIERRE PICARD (Aerospatiale, Les Mureaux, France), and PATRICK AUBRY (CNES, Toulouse, France) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 14 p.
(IAF PAPER 88-050)

Plans for the long duration flight/antenna representative experiment are presented. The experiment tests a large deployable structure made of carbon fiber composite which might be used in the future as the supporting structure of large size antennas or other instruments. The design, development, and qualification program of the experiment is discussed. Plans for a zero gravity test and to fly the experiment on the Mir space station are examined. R.B.

A89-17654#
THE COLUMBUS PROGRAMME - STATUS AND PERSPECTIVE
FREDRIK ENGSTROM (ESA, Paris, France) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 25 p.
(IAF PAPER 88-054)

The Columbus Development Program is reviewed, focusing on the development, construction, and flight of the Attached Pressurized Module, the Man-Tended Free-Flyer, and the Polar Platform. The ground infrastructure and preparation for initial operations are discussed. Hardware development, flight testing, and the astronaut team for the mission are also considered. R.B.

A89-17655#
PROGRAM STATUS AND PLAN OF JEM
Y. MORISHITA, N. SAITO, M. SAITO, Y. HORIKAWA, and K. HIGUCHI (National Space Development Agency of Japan, Tokyo) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 5 p.
(IAF PAPER 88-055)

The development of the Japanese Experiment Module (JEM) for the Space Station is reviewed. The design, operations, and information system of the JEM are discussed. Resource allocation for the development program and plans for future activities in the development of the JEM are examined. R.B.

A89-17662#
JEM INTEGRATED CONTROL AND MANAGEMENT SYSTEM (JEM OMA)
K. SHIRAKI, I. IIZUKA (National Space Development Agency of Japan, Tokyo), H. KOIZUMI, Y. TAKEUCHI (Mitsubishi Heavy Industries, Ltd., Tobishima, Japan), S. TAKAHASHI (Mitsubishi Heavy Industries, Ltd., Nagoya, Japan) et al. IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 7 p.
(IAF PAPER 88-069)

To assure adequate safety, reliability and maintainability of JEM (The Japanese Experiment Module), the concept of the Integrated Control and Management System was studied. As the result of the study, the control and management architecture, functional requirements, and software structure were clarified. Author

A89-17663#
COLUMBUS - DESIGN APPROACH TO MEET USER NEEDS
GORDON R. BOLTON and ANDREW H. MCGRATH (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 26 p.
(IAF PAPER 88-070)

This paper discusses how the Columbus design has evolved to meet user requirements while respecting other technical and programmatic constraints. User needs with regard to the Attached Pressurized Module, the Man-Tended Free Flyer, and the Polar Platform are reviewed. The design approach with regard to configuration, payloads. electrical power, cooling, data handling, and attitude are addressed. C.D.

A89-17664#
MAN SYSTEMS ASPECTS IN THE DESIGN CONCEPT OF THE COLUMBUS MAN-TENDED FREE-FLYER (MTFF)
HELMUT FRIEDRICH, MANFRED BAUNE, and JACQUELINE BAUNE (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IAF, International Astronautical Congress,

39th, Bangalore, India, Oct. 8-15, 1988. 14 p.
(IAF PAPER 88-075)

The effect of the temporary presence of man on the MTFF design concept is described. The requirements concerning the functions, safety, and redundancy of the vital spacecraft subsystems and the work environment for the astronauts are considered as well. It is noted that a next step in manned activities in space is an extended combined MTFF/Hermes mission where, in addition to MTFF servicing, payload processing will be conducted in the MTFF, involving the Hermes crew. K.K.

A89-17668#
MAIN RESULTS OF THE 'MIR' COMPLEX OPERATION
IU. P. SEMENOV IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 13 p.
(IAF PAPER 88-084)

Results from experiments performed on the Mir orbiting station are presented, including astrophysical, geophysical, technological, and biomedical experiments and visual observations. X-ray and UV stellar observations, the study of the physical processes in the high atmospheric and ionospheric layers, remote sensing for agricultural purposes, the study of semiconductor technology, and the production of construction materials in space are discussed. In addition, the production of highly pure medical and biological preparations through protein electrophoretic splitting and refining and experiments to determine the optimum conditions for cultivating higher plants in a space greenhouse are examined. R.B.

A89-17671#
OPERATIONS IMPACT ON COLUMBUS MTFF AND HERMES DESIGNS - A CONVERGING PROCESS
PATRICK EYMAR (Aerospatiale, Les Mureaux, France) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 8 p. refs
(IAF PAPER 88-089)

The design evolutions of the ESA Hermes STS and Man-Tended Free Flyer (MTFF) are recalled, with a focus on the problems encountered in making them operationally compatible (since the MTFF will be serviced by Hermes). The main steps in the individual design processes are listed and briefly characterized, and particular attention is given to the overall operational-design philosophy, the definition of the cargo set, cargo-set accommodation, and Hermes mission duration. Diagrams and drawings are provided. T.K.

A89-17672#
COLUMBUS DATA MANAGEMENT
X. LABORDE and PH. DELBEY (Matra Espace, Toulouse, France) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 6 p.
(IAF PAPER 88-091)

Plans for the data-processing and data-storage systems of Columbus, the ESA contribution to the International Space Station, are discussed. The need for high degrees of autonomy and automation is indicated; maintenance and servicing problems are examined; and the possibility of remote operation of scientific payloads is considered. Particular attention is given to fault tolerance and safety, system standards for communication protocols and software, standardized electrical interfaces, and the current Columbus data-system baseline technology (architecture, computers, memories and data base, software, and man-machine interfaces). A block diagram of the baseline system is provided. T.K.

A89-17673#
RESULTS OF PREPARING COLUMBUS UTILIZATION DURING PHASE B - PLANNING FOR PHASE C/D
F. UNZ (DFVLR, Cologne, Federal Republic of Germany), F. ROSSITTO (Ministero per il Coordinamento della Ricerca Scientifica e Tecnologica, Rome, Italy), and K. BAGOT (Royal Aerospace Establishment, Farnborough, England) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 9 p. refs
(IAF PAPER 88-093)

The current status of planning for European scientific utilization of the Columbus Attached Pressurized Module and Man-Tended Free Flyer spacecraft of the International Space Station is surveyed. Topics examined include the Columbus Payload Data Base (data files, architecture, and the organization of dissemination), the ground infrastructure for space experiments (user home bases, user support and operations center, payload operations and control center, and mission control center), and mission-implementation organization. The user centers now operational or under development in the FRG are listed and briefly characterized. T.K.

A89-17676#
BALCONY - A EUROPEAN SPACE STATION EXTERNAL STRUCTURE
GILLES DEBAS (Aerospatiale, Les Mureaux, France) and PIERRE DUTTO (CNES, Toulouse, France) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p.
(IAF PAPER 88-099)

A proposal for a balcony to provide for the addition of external payloads on the Space Station is presented. A balcony would serve as a link between payloads and the mother platform, and would be adaptable and modular to match the requirements of various payloads. The payload support functions of a balcony and the possible role of a balcony in EVA activites are discussed. Case scenarios for balcony use are given, including a Columbus scenario, and the case of the advanced manned Space Station. Candidate payloads, balcony architecture and operations, and three possible designs for a balcony are examined. R.B.

A89-17721#
LOGISTICS SUPPORT OF THE JAPANESE EXPERIMENT MODULE BY THE H-II ROCKET
YOJI SHIBATO, TAKAO ETO, YUKIO FUKUSHIMA, and HITOSHI TAKATSUKA (National Space Development Agency of Japan, Tokyo) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 6 p. refs
(IAF PAPER 88-199)

This paper describes salient design features of the Japanese Experiment Module (JEM), which will be attached to the Space Station. Special attention is given to the logistic support of the JEM (which is planned to become operational in 1990s) by the HOPE orbiter, which will be used for the resupply and the retrieval of the JEM, and the H-II rocket, which will be used to launch the HOPE. The concepts of HOPE and the H-II rocket are discussed together with the estimated logistics requirements of this system. Configuration diagrams are included. I.S.

A89-17722#
ARIANE TRANSFER VEHICLE IN SERVICE OF MAN IN ORBIT
N. DEUTSCHER, K. SCHEFOLD (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany), and C. COUGNET (Matra S.A., Toulouse, France) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 12 p. Sponsorship: European Space Research and Technology Centre.
(Contract ESTEC-7357/87-NL-NA(SC))
(IAF PAPER 88-200)

The Ariane Transfer Vehicle (ATV), an unmanned propulsion system that is designed to be carried by the Ariane 5 launch vehicle, will undertake the logistical support required by the International Space Station and the Man-Tended Free Flyer, carrying both pressurized and unpressurized cargo to these spacecraft and carrying away wastes. The ATV is an expendable vehicle, disposed of by burn-up during reentry, and will be available for initial operations in 1996. In order to minimize development costs and recurrent costs, the ATV design will incorporate existing hardware and software. O.C.

A89-17723#
THE PHASE 1 OF THE HERMES DEVELOPMENT PROGRAMME
J. J. CAPART (ESA, Toulouse, France) IAF, International

Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 7 p.
(IAF PAPER 88-201)

The main objective of the Phase I of the Hermes Development Program is to complete the system design and spaceplane configuration. The mission and operational interfaces of Hermes with Ariane 5 and Columbus are also studied in detail. The Phase I extends over a period of three years and has an overall envelope of 530 MAU. K.K.

A89-17724#
HERMES PAYLOAD ACCOMMODATION ASPECTS AND TRANSFER OPERATIONS TO COLUMBUS MTFF
M. C. DESJEAN-ARNOULD (CNES, Toulouse, France) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 6 p.
(IAF PAPER 88-202)

The Hermes cargo is discussed as well as payload accommodation. Commonality problems with MTFF are discussed with attention given to mechanical interfaces, power and thermal control interfaces, data exchange interfaces, and safety problems. In a discussion of Hermes turn-around, consideration is given to ground integration, flight operation, landing, and unloading. K.K.

A89-17778#
THE MEASURED AND PREDICTED MICRO-G EURECA ENVIRONMENT
W. HERFS, R. D. ANDRESEN (ESA, Columbus System and Projects Dept., Noordwijk, Netherlands), and D. EILERS (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 19 p. refs
(IAF PAPER 88-341)

Aspects of the interaction of the European Retrievable Carrier (EURECA) microgravity environment is discussed. The overall EURECA concept is reviewed, and the requirements for the microgravity environment of the EURECA platform are outlined. The design verification of EURECA by analysis and tests is examined and the predicted and measured EURECA microgravity environment is discussed with regard to gravity gradient, atmospheric drag, drag amd gravity gradient torques, attitude control and stabilization, structure dynamics, subsystem equipment, and payload instruments. The effects of the superposition of single-source impacts on EURECA is considered. C.D.

A89-17844#
MISSIONS AND SYSTEM REQUIREMENTS FOR AN ESCAPE VEHICLE WITHIN A EUROPEAN MANNED SPACE INFRASTRUCTURE
MAX GRIMARD and GILLES DEBAS (Aerospatiale, Les Mureaux, France) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 19 p.
(IAF PAPER 88-514)

A proposed escape system for an autonomous European manned space infrastructure (EMSI) is discussed. The EMSI framework and a safety analysis for the EMSI are presented. The mission functions and design requirements for an EMSI escape vehicle are examined in detail. The applications for space stations are considered. R.B.

A89-18313#
LOGISTICS ASPECTS ASSOCIATED WITH THE HERMES SPACEPLANE TURNAROUND AND CARGO PREPARATION
J. HERHOLZ and G. VALENTINY (ESA, Paris, France) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 9 p.
(AIAA PAPER 88-4736)

ESA has undertaken the development of logistics operational concepts for Hermes spacecraft missions tasked with the servicing of the Columbus autonomous laboratory. The ground-infrastructure and mission-related cargo-processing activities cycle will be divided into six phases: payload preparation in view of Hermes interface specifications, cargo integration and functional verification in Europe, cargo/spaceplane integration in Kourou, access to cargo during Hermes/Ariane integration, orbital cargo deployment, and postlanding cargo retrieval. An account is given of the Hermes Integrated Logistics Management System. O.C.

A89-18348
COLUMBUS AIMS AT AUTONOMY
TIM FURNISS Flight International (ISSN 0015-3710), vol. 134, Nov. 5, 1988, p. 41-44.

The Columbus program will be ESA's contribution to the NASA International Space Station Freedom, and will fundamentally depend on the reliability and productivity of the Ariane 5 launcher and its Hermes manned upper stage. In order to ensure a high data-transfer rate from Columbus to Europe, an essential element that is envisioned for an autonomous system such as Columbus is a set of S-, Ka- and Ku-band satellites; three such are planned. The roles of the Man-Tended Free Flyer and Attached Pressurized Modules of the Freedom system are discussed. O.C.

A89-18433
NONLINEAR OSCILLATIONS OF A SYSTEM OF TWO BODIES CONNECTED BY A FLEXIBLE ROD IN A CENTRAL FORCE FIELD [NELINEINYE KOLEBANIIA SISTEMY DVUKH TEL, SOEDINENNYKH GIBKIM STERZHNEM, V TSENTRAL'NOM SILOVOM POLE]
V. I. GULIAEV, V. L. KOSHKIN, P. P. LIZUNOV, and N. N. PRUDENKO Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 26, Sept.-Oct. 1988, p. 669-674. In Russian. refs

An analysis is made of the oscillations of two bodies connected by a flexible rod with respect to their mass center moving in an elliptical Keplerian orbit. The effect of the reduced mass of the system and the stiffness of the rod on the stability and mode of the relative motion is investigated. B.J.

A89-18449
INVESTIGATION OF THE EFFECTS OF A JET AND THERMAL RADIATION FROM AN ELECTROROCKET ENGINE ON A SPACECRAFT SOLAR ARRAY [ISSLEDOVANIE VOZDEISTVIIA STRUI I TEPLOVOGO IZLUCHENIIA ELEKTRORAKETNOGO DVIGATELIA NA SOLNECHNYE BATAREI KOSMICHESKOGO APPARATA]
S. N. ASKHABOV, D. P. GRDLICHKO, A. I. KOZLOV, V. A. KOLOSKOV, A. B. PETROV et al. Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 26, Sept.-Oct. 1988, p. 796-798. In Russian.

The paper presents an investigation of the stability of a solar array under the prolonged effect of a jet and thermal radiation from an electrojet engine, simulated by two models of a stationary plasma engine. It is concluded that the results obtained reflect with sufficient accuracy the atomization of the protective coatings of solar cells and solar-array structural elements under the effect of an ion beam under conditions of sun-synchronous and lower orbits. B.J.

A89-19943#
TYPICAL APPLICATION OF CAD/CAE IN SPACE STATION PRELIMINARY DESIGN
KATSUHIKO TAKAHASHI and YOSHIHARU HANAI Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 28, July 1988, p. 197-201. In Japanese, with abstract in English.

The role of CAD/CAE in the Japanese Experiment Module (JEM), Japan's contribution to the Space Station project, is examined. It is shown that CAD/CAE is significantly efficient in hardware layout design, component/structure interference analysis, window field of view analysis, manipulator operability analysis in equipment replacement, drawing development, data exchange with NASA and participating companies, and efficiency of data usage. C.D.

A89-19947#
PRELIMINARY TECHNOLOGY DEVELOPMENT TESTS OF THERMAL CONTROL SYSTEM FOR JAPANESE EXPERIMENT MODULE (JEM)
Ishikawajima-Harima Engineering Review (ISSN 0578-7904), vol. 28, July 1988, p. 218-224. In Japanese, with abstract in English. Research supported by the National Space Development Agency of Japan. refs

Waste heat generated in JEM is collected and transported by the thermal control system (TCS), and rejected to space primarily from Space Station central radiator. The JEM TCS is divided into two heat transport loops and four heat rejection and collection loops. Preliminary technology development tests for the thermal control system were performed under fiscal-61, fiscal-62 NASDA contract. Component tests for a mechanical pump, heat exchangers, and cold plates were performed to get fundamental data. Considering design of a future active thermal control system, it is necessary to understand the behavior of the two-phase flow in low-gravity environment. A fundamental study on the ground was carried out using a drop tower. A thermal control test facility was constructed to simulate JEM TCS and computer simulation was carried out simultaneously. Results of the experiment and computer analyses were compared with each other, and a mathematical model was modified to apply the next phase design. Author

A89-20231
USE OF PRIMARY AND REGENERATIVE FUEL CELL SYSTEMS IN THE EUROPEAN SPACE FLIGHT SCENARIO [EINSATZ VON PRIMAEREN UND REGENERATIVEN BRENNSTOFFZELLSYSTEMEN IM EUROPAEISCHEN RAUMFAHRTSZENARIO]
JUERGEN HYEN and HANS GEHRKE (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) IN: Yearbook 1987 II; DGLR, Annual Meeting, Berlin, Federal Republic of Germany, Oct. 5-7, 1987, Reports. Bonn, Deutsche Gesellschaft fuer Luft- und Raumfahrt, 1987, p. 650-654. In German.
(DGLR PAPER 87-117)

The present state of the art and the possibility for the future of primary and regenerative fuel cell systems in European space missions are addressed. The usage possibilities examined include transport in low orbit, manned space stations, unmanned platforms, orbital communications infrastructure, and orbital elements for mounting, maintenance, and repair. A regenerative fuel cell system is diagrammed. C.D.

A89-20659#
TECHNOLOGICAL ACTIVITIES OF ESA IN VIEW OF THE ROBOTIC AND AUTOMATIC APPLICATION IN SPACE
I. BRAGA (ESA, European Space Research and Technology Centre, Noordwijk, Netherlands) AIAA and NASA, International Symposium on Space Automation and Robotics, 1st, Arlington, VA, Nov. 29, 30, 1988. 11 p.
(AIAA PAPER 88-5010)

ESA activities related to robotics and automatic space applications are reviewed. The internal robotics systems for the Man-tended Free Flyer are discussed, including the central robot system, the manipulator arm, wrist, and end-effector subsystems, the movable manipulator base subsytem, and the multirack robot system. External robotics applications for the Hermes Robot Arm (HERA) are examined. The HERA tasks are outlined, and the HERA structure, vision system, and control concept are described. Support facilities for robotics research are outlined, including simulators and demonstrators. R.B.

A89-20748
THE WAY TO MARS
V. GLUSHKO (AN SSSR, Moscow, USSR), L. GORSHKOV (AN SSSR, Sovet Interkosmos, Moscow, USSR), and Y. SEMENOV Planetary Report (ISSN 0736-3680), vol. 8, Nov.-Dec. 1988, p. 4-8.

An article from the Soviet newspaper, Pravda, is presented, which discusses issues related to missions to Mars. The type of vehicle needed for a Martian mission is examined, including the propulsion system, construction of the vehicle in earth orbit, living quarters, safety considerations, and the landing vehicle. Options for the mission route and ways of returning to earth are considered. Also, a proposal for a three phase program leading up to a manned mission to Mars is outlined. R.B.

A89-21400
SOVIET UNION TO BROADEN COMMERCIAL SPACE ACTIVITIES
JEFFREY M. LENOROVITZ Aviation Week and Space Technology (ISSN 0005-2175), vol. 129, Dec. 19, 1988, p. 92, 93, 95.

Commercial space ventures undertaken by the Soviet Union are reviewed. Services offered by the Soviet Union include telecommunications transponder capacity, the availability of manned flights on space stations, Photon microgravity capsules, the use of Soviet launch sites and factories by foreign customers, and remote sensing imagery. Also, efforts at marketing these services, changes in Soviet policy which have lead to more commercial space activities, and past and potential customers for Soviet space activities are discussed. R.B.

A89-21403
EVA SAFETY [SECURITE DES ACTIVITES SPATIALES EXTRA-VEHICULAIRES]
J. LALOE (Avions Marcel Dassault-Breguet Aviation, Saint-Cloud, France) L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 132, 1988, p. 23-30. In French.

The applications, risks, and safety objectives of EVA are discussed. Goals of EVA safety include protecting the astronaut from external hazards such as radiation and debris, controlling the internal space-suit environment, and assuring the physical and psychological health of the astronaut. Other factors considered include the mobility and dexterity of digits and limbs, EVA locomotion, the mother-vessel/space-suit interface, and EVA procedures such as prebreathing prior to partial depressurization and airlock tests. R.R.

A89-21790#
INDUSTRIAL SPACE ACTIVITIES IN THE NETHERLANDS [INDUSTRIELE RUIMTEVAARTACTIVITEITEN IN NEDERLAND]
D. DE HOOP Ruimtevaart, Oct. 1988, p. 5-111. In Dutch.

The role of the Netherlands aerospace industry in Dutch and ESA space programs is surveyed and illustrated with drawings and photographs. Fields covered include scientific satellites, microgravity experiments, telecommunications, remote sensing, the Columbus and Hermes projects, and technology development. The activities of individual laboratories and companies are then characterized in detail, and the space budgets of western European countries for the period 1972-1987 are listed in a table. T.K.

A89-22265
THE SOVIET MANNED SPACE PROGRAM
PHILLIP CLARK (Commercial Space Technologies, Ltd., London, England) New York, Orion Books, 1988, 192 p. refs

The history of Soviet manned space missions is surveyed and illustrated with extensive photographs and drawings. Chapters are devoted to the early stages of the Soviet space program, the development of Vostok, the Voskhod missions, Soyuz and the manned lunar program, the first Soyuz flights, the first space station, the military and civilian Salyut missions, and the solo Soyuz flights. Consideration is given to new spacecraft to support Salyut, the second-generation Salyut 6, the mission of Salyut 7, the Mir modular space station, and future trends. Also provided are biographical sketches of major figures in the Soviet space program and tables of numerical data on launch vehicles, manned missions, and cosmonauts. T.K.

A89-22618#
THE COLUMBUS DEVELOPMENT PROGRAMME
F. ENGSTROM, J.-J. DORDAIN, R. BARBERA, G. GIAMPALMO, and H. AREND (ESA, Directorate of Space Station and Platforms,

Paris, France) ESA Bulletin (ISSN 0376-4265), no. 56, Nov. 1988, p. 10-18.

The Columbus Development Program, started in January 1988, represents Europe's major contribution to the cooperation with the United States, Japan and Canada in the International Space-Station Program. It covers the development, manufacture and delivery to orbit of three space elements - an Attached Pressurized Module (APM), a Man-Tended Free-Flyer (MTFF), and a Polar Platform (PPF), buildup of the related ground infrastructure, and preparation for initial operations and subsequent utilization. Author

A89-22619#
A NEW GENERATION OF SPACECRAFT CONTROL SYSTEM - 'SCOS'
C. MAZZA and J. F. KAUFELER (ESA, Computer Dept., Darmstadt, Federal Republic of Germany) ESA Bulletin (ISSN 0376-4265), no. 56, Nov. 1988, p. 19-23.

A software package, the Spacecraft Control and Operations System (SCOS), has been developed as a new control system for Hipparcos, Eureca, ERS-1, and all future missions to be supported by the Dedicated Mission-Support system. The system supports packetized and fixed TDM telemetry. The SCOS architecture, including the functional and mission-specific subsystems of the application layer and the middleware subsystems of the support layer, is described in detail. R.R.

A89-22891#
PROTECTION OF MANNED MODULES AGAINST MICROMETEORITES AND SPACE DEBRIS [ABSCHIRMUNG BEMANNTER MODULE GEGEN MIKROMETEORITEN UND SPACE DEBRIS]
ERNST BAUER (MBB-ERNO Raumfahrttechnik GmbH, Bremen, Federal Republic of Germany) Hermann Oberth Gesellschaft, Raumfahrtkongress, 37th, Hanover, Federal Republic of Germany, May 7, 1988, Paper. 32 p. In German. refs
(MBB-UO-0004-88-PUB)

The protective measures being taken for the Columbus space vehicle to protect it against micrometeorites and space debris are discussed. The meteorites and debris environment is described, and the resulting safety requirements are examined. The design of the protective structures for Columbus is addressed, and the results of damage studies on those structures are reviewed. C.D.

A89-23078
ARCHITECTURES AND TECHNOLOGIES FOR COLUMBUS AND HERMES ON-BOARD DATA SYSTEMS
X. LABORDE, A. BLANC, and D. PERARNAUD (Matra Espace, Toulouse, France) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 42, Jan. 1989, p. 21-25.

An account is given of the Columbus and Hermes data system architectures, giving attention to the variety of required implementing technologies involved and emphasizing the aspects of these technologies that are held in common by both programs. The Consultative Committee for Space Data Systems standards' implementation is discussed, together with that of recent advancements in man-machine interface technology for ground data systems. Preliminary results obtained with the Columbus Data Management System Test Bed are presented. O.C.

A89-23719
QUALITY INDEX EXCHANGE DIAGRAM OF SPACECRAFT APPROACH AND DOCKING TRAJECTORIES UNDER ABNORMAL OPERATING CONDITIONS [DIAGRAMMA OBMENA POKAZATELEI KACHESTVA SOPRIAZHENIIA TRAEKTORII SBLIZHENIIA I PRICHALIVANIIA KOSMICHESKOGO APPARATA V NESHTATNYKH SITUATSIIAKH]
N. S. GUBONIN Kosmicheskie Issledovaniia (ISSN 0023-4206), vol. 26, Nov.-Dec. 1988, p. 946-949. In Russian.

A89-24195
OPTIMIZATION OF SPACECRAFT THERMAL CONTROL SYSTEMS [OPTIMIZATSIIA SISTEM TERMOREGULIROVANIIA KOSMICHESKIKH APPARATOV]
VLADIMIR V. MALOZEMOV and NATAL'IA S. KUDRIAVTSEVA Moscow, Izdatel'stvo Mashinostroenie, 1988, 112 p. In Russian. refs

Mathematical models of spacecraft thermal-control units and systems are presented. A method is developed for solving thermal-control optimization problems. In addition, engineering methods and algorithms are developed for choosing appropriate design parameters for spacecraft thermal-control systems for stationary and nonstationary operating conditions. B.J.

A89-24662
NATURAL FREQUENCIES AND STABILITY OF IMMISCIBLE CYLINDRICAL Z-INDEPENDENT LIQUID SYSTEMS
HELMUT F. BAUER (Muenchen, Universitaet der Bundeswehr, Neubiberg, Federal Republic of Germany) Applied Microgravity Technology (ISSN 0931-9530), vol. 1, Oct. 1987, p. 11-26. refs

An attempt is made to provide a survey of the vibrational behavior of various immiscible liquid systems which may be used as basic elements in an orbiting space laboratory. The effect of gravity is neglected. Cases are given for nonrotating and rotating liquid bridges consisting of frictionless, viscous, and viscoelastic liquids. K.K.

A89-24672
OVERVIEW OF JAPANESE MICROGRAVITY ACTIVITIES
HISAO AZUMA (National Aerospace Laboratory, Chofu, Japan) Applied Microgravity Technology (ISSN 0931-9530), vol. 1, July 1988, p. 109-114.

Microgravity research in Japan is reviewed, including plans for future microgravity experiments. Equipment and experiments for studying the material processing, life science, crystal growth, electronics, and biotechnology applications of microgravity are listed. Plans for the Japanese Experimental Module on the Space Station are discussed. In addition, the private and government organizations involved in microgravity research in Japan are examined. R.B.

A89-25080#
ARIANE 5 TRANSFER VEHICLE (ATV) FOR LOGISTICS FLIGHTS TOWARDS ISS
CHRISTOPHE BONNAL (Aerospatiale, Les Mureaux, France) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 9 p.
(AIAA PAPER 89-0091)

Ariane 5 may be used as a complementary expendable launch vehicle for International Space Station (ISS) servicing. The infrastructure definition and traffic identification, mission analysis, safety requirements, and ATV concepts pertaining to this function are presented. An ATV subsystem description is given for the structure, propulsion, thermal control, power supply, communications, data handling, mechanisms, and payload accommodation. C.D.

A89-26379#
ARIES - THE ARIANE 5 EXTENDED STAGE FOR ORBITAL TRANSFER AND RENDEZVOUS
PIERRE MOLETTE (Matra Espace, Toulouse, France) IN: Commercial opportunities in space; Symposium, Taipei, Republic of China, Apr. 19-24, 1987, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 34-49.

The Ariane 5 Extended Stage (Aries) expendable vehicle, which can be configured as a basic vehicle or with additional extension packages for rendezvous and docking capabilities, is examined. The potential missions for the Aries are described, including the launch of a pressurized module towards the operational Space Station, the launch of logistics modules to resupply the Space Station, and the launch of a large payload module or fuel tanks towards an automatic platform. Also, the Aries architecture, the

adaptation of the Ariane 5 Vehicle Equipment Bay to the Aries mission, and the general characteristics and performance of the Aries vehicle are discussed. R.B.

A89-26380#
COLUMBUS OPERATIONS - PLANNING AND EXECUTION
JOACHIM KEHR (DFVLR, Oberpfaffenhofen, Federal Republic of Germany) IN: Commercial opportunities in space; Symposium, Taipei, Republic of China, Apr. 19-24, 1987, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 50-65.

The planning and execution management processes for the Columbus program are discussed, focusing on the European Attached Pressurized Module for the Space Station. The activities, outputs, and interfaces at the strategic, tactical, and execution planning levels are examined. User involvement in the planning process is emphasized. Planning procedures are proposed with respect to the determination and inclusion of payloads, resource allocation, and safety. It is suggested that decentralized tactical planning best suits the program's goal of achieving operational autonomy within the international framework of the Space Station. R.B.

A89-27906
EUROPEAN SPACE SUIT SYSTEM BASELINE
NIKOLAUS HERBER and ROLAND VAETH (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 15 p.
(SAE PAPER 881115)

This paper provides a description of the current European Space Suit System (ESSS) status. The ESSS is foreseen for servicing of various elements of space infrastructure within typical operational scenarios based on Hermes. As a result of different EVA studies, the ESSS concept has been defined and structured in three modules: the EVA Suit Enclosure Module (ESEM), the EVA Life Support Module (ELSM), and the EVA Information and Communication Module (EICM). The main portion of the description herein is provided for the ELSM, since this module has been studied in more detail up to now in comparison with the ESEM and the EICM. Author

A89-27907
REGENERATIVE CO2-CONTROL - A TECHNOLOGY DEVELOPMENT FOR EUROPEAN MANNED SPACE PROGRAMS
HELMUT PREISS, WALTER BREITLING, and HELMUT FUNKE (Dornier System GmbH, Friedrichshafen, Federal Republic of Germany) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 9 p. Research supported by DFVLR.
(SAE PAPER 881116)

This paper presents the design and the test results of a regenerative carbon dioxide control system using solid ion exchange materials. The system applies a two-bed approach with regeneration by steam and is designed for three-man operation. Two adsorber materials were investigated and applied throughout the tests. The system contains an evaporator, two adsorber beds, a condensing heat exchanger, and an electronic controller. Test results concern the major performance parameters, such as CO2-loading, pressure loss, moisture range, stability ranges and energy required for desorption. Furthermore, dedicated material analysis has been performed regarding offgassing products during operation. Author

A89-29110
REPORT OF RESEARCH FORUM ON SPACE ROBOTICS AND AUTOMATION: EXECUTIVE SUMMARY
YOJI UMETANI, KAZUYA YOSHIDA (Tokyo Institute of Technology, Japan), YOSHIAKI OKAMI (National Aerospace Laboratory, Tokyo, Japan), MASARU UCHIYAMA (Tohoku University, Sendai, Japan), TSUTOMU IWATA (National Space Development Agency of Japan, Tokyo) et al. Research supported by the National Space Development Agency of Japan. Tokyo, Japan Space Utilization Promotion Center, 1988, 37 p.

A NASDA report on Japanese policies concerning space robotics and automation development is summarized. A scenario in which orbiting robots construct and operate space structures is presented and the element technologies needed to realize the scenario are discussed. Recommendations for Japanese policy are given, focusing on three project proposals: the construction of space structures using robots, the development of a space experiment module, and the creation of ground-based testing facilities for the performance evaluation and verification of space robots. R.B.

A89-29404
RATIONALE AND REQUIREMENTS FOR THE MULTI-ROLE CAPSULE
C. M. HEMPSELL (British Aerospace, PLC, Space and Communications Div., Stevenage, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 42, Feb. 1989, p. 58-66.

The Multi-Role Capsule (MRC) is a concept for a recoverable capsule capable of working in unmanned and manned modes. It would be launched on Ariane 4, and be capable of carrying up to six men or 1500 kg of cargo. It would undertake a number of roles, supporting space station program with crew delivery and emergency crew return; other missions could include independent manned operations and an unmanned microgravity laboratory. The concept has been the subject of a preliminary study to establish the feasibility and potential. The paper discusses the reasons why the MRC study was undertaken an the rationale for setting the system requirements. Author

A89-29651#
JAPAN BROADENS ITS AEROSPACE INTERESTS
NEIL W. DAVIS Aerospace America (ISSN 0740-722X), vol. 27, March 1989, p. 12-18.

Japanese aerospace research, development, and production programs are reviewed. The products, American and European partners, and large shareholders of the ten leading Japanese aerospace companies are listed. The R&D programs discussed include the FSX close-supporter fighter, the four-engine quiet short takeoff and landing test bed, a hypersonic transport, the H-II launch vehicle, a reusable orbital aircraft named HOPE, and the Japanese Experiment Module for the Space Station. In addition, computer science and observation and communication satellite programs are considered. R.B.

A89-31759
MIR MISSION REPORT
NEVILLE KIDGER Spaceflight (ISSN 0038-6340), vol. 31, March 1989, p. 77-81.

The experiments and operations on the joint Soviet/French Mir mission are discussed. Biomedical experiments on the mission include echograph ultrasound tests of cardiac activity, the study of hormonal changes experienced during space flight, and the determination of sensory and motor physiology in microgravity. Materials science and physical experiments include studies of the behavior of polymeric materials, the nature and distribution of dust in space, and the evolution of solar absorptivity and emissivity. The installation of the ERA structure and the return of the Soyuz TM-6 are described. R.B.

N89-11643# Max-Planck-Inst. fuer Astronomie, Heidelberg (Germany, F.R.).
SPACE OBSERVATIONS FOR INFRARED AND SUBMILLIMETER ASTRONOMY
DIETRICH LEMKE *In* ESA, Space Science and Fundamental Physics p 81-92 May 1988
Avail: NTIS HC A10/MF A01

The Infrared Astronomy Satellite, the infrared telescope on Spacelab, cryogenic telescopes, and the Infrared Space Observatory are described. The Cosmic Background Explorer,

Hubble Space Telescope, Shuttle Infrared Telescope Facility, the Far Infrared and Submillimeter Telescope, and the Large Deployable Reflector are introduced. ESA

N89-11770*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SPACE POWER TECHNOLOGIES
RONALD J. SOVIE *In* NASA, Washington, Technology for Future NASA Missions: Civil Space Technology Initiative (CSTI) and Pathfinder p 193-218 Sep. 1988
Avail: NTIS HC A23/MF A01 CSCL 22/1

Information is given in viewgraph form on space power technologies. Energy conversion, the role of nuclear power in space, lunar and Mars bases, and the Pathfinder program are covered. R.J.F.

N89-11789# European Space Agency, Paris (France).
PREPARING FOR HERMES: SPACE TRANSPORTATION SYSTEMS; LONG TERM PREPARATORY PROGRAM. RESULTS OF TECHNOLOGICAL STUDIES Interim Report, 1988
NORMAN LONGDON, ed. Aug. 1988 68 p Original contains color illustrations
(ESA-SP-1096; ISSN-0379-6566; ETN-88-93159) Avail: NTIS HC A04/MF A01

Hermes operational and spacecraft technology studies are summarized. Requirements and concepts for manned rendezvous and docking; a docking adaptor mechanism; transfer airlock requirements; control of docked Hermes-Columbus elements; extravehicular activities; general requirements, human factors engineering, and life support systems; protection against radiation in space; and manipulator adaptation were studied. High performance composite structures; propulsion systems for reusable man-rated spacecraft; signal compression; optical bus; communication processors; antenna pattern prediction software; common power technology; fuel cells for space use; environmental control and life support technology; and subsonic wind tunnel tests are discussed. ESA

N89-12502# Bundesministerium fuer Forschung und Technologie, Bonn (Germany, F.R.).
AGREEMENT ON THE INTERNATIONAL SPACE STATION AND THE COLUMBUS PROGRAM. DOCUMENTATION [UEBEREINKOMMEN UEBER DIE INTERNATIONALE RAUMSTATION UND DAS PROGRAMM COLUMBUS. DOKUMENTATION]
22 Jul. 1988 95 p In GERMAN
(REPT-27/88; ETN-88-93226) Avail: NTIS HC A05/MF A01

Agreements between NASA, ESA, Japan, and Canada on the collaboration for the detailed design, development, operation, and use of the manned orbital space station of Columbus program are presented. Main points are listed and the texts of resolutions are given. ESA

N89-12978# British Aerospace Public Ltd. Co., Bristol (England). Space and Communications Div.
EUROPEAN REMOTE SENSING SATELLITE PLATFORMS FOR THE 1990'S
P. TRUSS *In* ESA, Proceedings of the 1988 International Geoscience and Remote Sensing Symposium (IGARSS 1988) on Remote Sensing: Moving Towards the 21st Century, Volume 1 p 171-174 Aug. 1988
Avail: NTIS HC A99/MF E03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 120 US dollars or 250 Dutch guilders

Requirements and constraints on a polar orbiting remote sensing system are reviewed. It is concluded that a series of 2 ton payload multi-mission platforms achieve the defined objectives. ESA

N89-12983# Marconi Space and Defence Systems Ltd., Portsmouth (England). Remote Sensing and Science Div.
ON-ORBIT SERVICING AND COST EFFECTIVENESS OF COLUMBUS POLAR PLATFORM CONCEPTS
R. G. W. HATHAWAY *In* ESA, Proceedings of the 1988 International Geoscience and Remote Sensing Symposium (IGARSS 1988) on Remote Sensing: Moving Towards the 21st Century, Volume 1 p 191-194 Aug. 1988
Avail: NTIS HC A99/MF E03; ESA Publications Div., ESTEC, Noordwijk, Netherlands, 120 US dollars or 250 Dutch guilders

Payload servicing of a 17-instrument Polar Platform complement is determined from the available design data, reliability of the platform subsystems, and the servicing interval of each component. On-orbit and ground servicing analytical background and cost modeling are summarized. The most suitable grouping of the scientific and commercially biased instruments and their servicing needs is discussed. It is suggested that dedicated platforms are more cost effective in terms of servicing lifetime. The Orbital Replacement Unit philosophy is considered and its effect on basic design concepts are reflected in the robotic and extra vehicular activity approach. ESA

N89-14245*# National Aeronautics and Space Administration, Washington, DC.
CURRENT ACHIEVEMENTS IN COSMONAUTICS
L. A. YERLYKIN, ed. Nov. 1988 62 p Transl. into ENGLISH from Novoye v Zhizni, Nauke, Tekhnike: Seriya Kosmonavtika, Astronomiya (USSR), no. 12, 1987 p 1-64 Transl. by Scientific Translation Service, Santa Barbara, Calif.
(Contract NASW-4307)
(NASA-TT-20365; NAS 1.77:20365) Avail: NTIS HC A04/MF A01 CSCL 22/1

The articles presented in this collection of works tell the latest achievements in Soviet cosmonautics: the regular expedition of cosmonauts to the Mir orbital space station, and the successful development of USSR international cooperation in the sphere of cosmonautics. Information is alo presented on the start of operation of the Japanese booster rocket. Author

N89-14937# European Space Agency, Paris (France).
ESA'S ACTIVITIES REPORT Annual Report, 1987
NORMAN LONGDON, ed., T. D. GUYENNE, ed., and JAMES HUNT, ed. May 1988 223 p Original contains color illustrations
(ISSN-0258-025X; ETN-89-93586) Avail: NTIS HC A10/MF A01

The ESA Ulysses, Space Telescope, HIPPARCOS, ISO, STSP, Earthnet, microgravity programs, earth observation programs, telecommunications programs, Ariane 4 and 5 launchers, Hermes, Columbus, Eureka, and Spacelab research and development are summarized. ESA

N89-17022# National Space Development Agency, Tokyo (Japan). Space Experiment Group.
SPACE UTILIZATION PROMOTION PROGRAM OF NASDA
K. YANAGAWA, R. KANKI, T. AMAIKE, and N. TAKEDA *In* National Research Council of Canada, Workshop on Microgravity Experimentation in Aircraft and Rockets p 17-23 1988
Avail: NTIS HC A07/MF A01; also available from Publication Sales and Distribution, National Research Council of Canada, Ottawa, ON, Canada K1A OR6

Current space research and development trends in Japan include: (1) Expectation of environment utilization like microgravity in space besides earth observation or communication terminal point; (2) Acquisition of new knowledge from space research and development; (3) Contribution to global social and economical development through the advancement of science and technology; (4) International cooperation based on peaceful purposes; and (5) Development of manned space activities for the next era. Japan has decided to participate in NASA's proposed international space station program with the Japanese Experiment Module (JEM) consisting of pressurized module, exposed facility, and logistic module. Author

N89-18503# Erno Raumfahrttechnik G.m.b.H. Bremen (Germany, F.R.).
STUDY OF IN-ORBIT SERVICING OF COLUMBUS ELEMENTS BY ALV, EXECUTIVE SUMMARY

Paris, France ESA Mar. 1988 86 p
(Contract ESTEC-7343/87-NL-MA(SC))
(ESA-CR(P)-2675; ETN-89-93929) Avail: NTIS HC A05/MF A01

An orbital servicing concept, especially for Columbus, based on an Ariane 5 logistics vehicle (ALV) is shown to be feasible. The ALV concept meets all the performance requirements, including safety for transporting logistics resupplies to the space station elements. Deletion of the ALV capability to perform active proximity maneuvers greatly reduces system complexity. Replacement of a large mono tank by separate tanks increases overall safety, deletes tank emptying operation, and the need for additional tanks. The separate tank concept reduces overall height of stage with associated mass savings on the interstage. The propulsion stage proposed can be used as basic stage for all Ariane 5 applications using 20 kN engine together with 2, 4, or 6 tanks for LEO-GTO missions. Attached pressurized module downloads must be returned by STS. The ALV offers very large free capacity for accommodating all types of expendable equipment, trash, waste products for atmospheric burn-up. Pressurized cargo modules were designed for worst case docking to the space station (180 days) offering pressurized storage capability, or umpressurized CM operating as tank farm. ESA

N89-18756# Logica Ltd., London (England).
THE COLUMBUS POLAR PLATFORM GROUND SEGMENT
D. C. FERNS and D. W. S. LODGE (Royal Aircraft Establishment, London, England) *In* ESA, Proceedings of the 1988 International Geoscience and Remote Sensing Symposium (IGARSS) '88 on Remote Sensing: Moving Towards the 21st Century, Volume 3 p 1485-1490 Aug. 1988
Avail: NTIS HC A99/MF A01; ESA Publications Division, ESTEC, Noordwijk, Netherlands, $120 US or 250 Dutch guilders

An industrial phase A study of the Polar Platform ground segment was carried out to provide outline design and costs to allow the respective national authorities to decide whether to commit to ESA to provide the facilities described. The aim was to provide a complete service to the user taking account of the rest of the European space and ground infrastructure. The main design drivers were the communications interfaces. The study identified all the facilities needed by the Polar Platform, analyzed the requirements in each case, and developed an outline design based on the distribution of current and committed facilities in the U.K. and Norway. ESA

N89-19105# Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne (Germany, F.R.). Hauptabteilung Projekte und Mikrogravitation.
MISSION POSSIBILITIES AND HARDWARE CONCEPTS [MISSIONSGELEGENHEITEN UND HARDWARE-KONZEPTE]
H. BINNENBRUCK *In its* Second Summer School on Microgravity. 2: Life Sciences as Main Subject p 11-23 Jun. 1988 In GERMAN
Avail: NTIS HC A09/MF A01

Microgravitational mission technical charts and concepts are described. Microgravity research and experiments, MICROBA mission sequence, ORBIS concept status, shuttle-Spacelab flight profile, Spacelab double rack and EURECA system, flight scenario, capabilities and core payload are shown. ESA

N89-19117# Deutsche Sporthochschule, Cologne (Germany, F.R.). Physiologisches Inst.
PROSPECTIVE: FROM SPACELAB TO MARS [AUSBLICK: VOM SPACELAB ZUM MARS]
J. STEGEMANN *In its* Second Summer School on Microgravity. 2: Life Sciences as Main Subject p 175-183 Jun. 1988 In GERMAN
Avail: NTIS HC A09/MF A01

Manned or unmanned spaceflights are reviewed, and it is suggested that Mars will be a space station like an orbital station of today. Human physiological and psychological adaptability are the main barriers. ESA

N89-19128# British Aerospace Public Ltd. Co., Bristol (England). Space and Communications Div.
EVA SYSTEM REQUIREMENTS AND DESIGN CONCEPTS STUDY, PHASE 2 Final Report
T. J. CARTWRIGHT, J. TAILHADES, and M. SCHEID Paris, France ESA Jun. 1988 225 p Prepared in cooperation with Matra Espace, Paris-Velizy, France, Sener S.A., Madrid, Spain, and McDonnell Douglas, Long Beach, CA
(Contract ESA-7324/87-NL-MA(SC))
(BAE-TP-9035; ESA-CR(P)-2676; ETN-89-93930) Avail: NTIS HC A10/MF A01

A European extravehicular activity (EVA) system baseline similar to the STS baseline was derived from analysis of Hermes/Columbus and other ESA manned missions. The ESA suit, however, uses single walled laminate materials. Equipment heat dissipations are collected via cold plates. The sublimator is augmented by a heat storage unit. Primary oxygen storage uses a high pressure nonrechargeable system. The prime mover consists of a separate axial fan, paristaltic pump, and high speed rotary separator. The EVA information/communication module (EICM) uses a digital communications system. The EICM offers a more sophisticated automatic checkout and data display capability than the STS system. The technology assessment indicates that the development of the defined European EVA system lies within the capabilities of European industry although potentially technology transfer from the USA could have substantial benefits. ESA

N89-19816# Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (Germany, F.R.).
STUDY ON CHECKOUT OF FLIGHT UNITS AND SUBSYSTEMS Final Report
W. BERGHOFER and S. Y. OVADYA Paris, France ESA Jun. 1988 130 p
(Contract ESA-5974/84)
(ESA-CR(P)-2693; ETN-89-93937) Avail: NTIS HC A07/MF A01

Tradeoffs were performed to derive the ground support requirements of TV-SAT. The interfaces between checkout equipment, onboard data handling, and test facilities were defined. The European Test Operation Langage and AS-BASIC were compared in terms of utilization, support, and performance. Remote checkout for extravehicular activity (EVA) was studied. It is shown that it is not possible to perform EVA without local monitoring, control of the acquired data and their transmission. Thus, as a windfall product remote checkout becomes available for the whole life of the EVA space suit system, and should be used to reduce cost and improve efficiency of the whole system. ESA

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SUPPORT SPACECRAFT

Includes design, analysis, requirements, trade studies and simulations of Space Station support spacecraft including the orbital transfer vehicle (OTV) and the orbital manuvering vehicle (OMV).

A89-12705
OPTIMAL TRAJECTORIES FOR TIME-CONSTRAINED RENDEZVOUS BETWEEN ARBITRARY CONIC ORBITS
LINDA J. WELLNITZ (TRW, Inc., TRW Space and Technology Group, Redondo Beach, CA) and JOHN E. PRUSSING (Illinois, University, Urbana) IN: Astrodynamics 1987; Proceedings of the AAS/AIAA Astrodynamics Conference, Kalispell, MT, Aug. 10-13, 1987. Part 2. San Diego, CA, Univelt, Inc., 1988, p. 1501-1513. refs
(AAS PAPER 87-539)

Optimal impulsive trajectories are computed for time-constrained rendezvous between arbitrary conic orbits. Primer vector theory is used to determine how the cost, in terms of delta V, can be minimized by the addition of initial and final coast periods, and by

the addition of midcourse impulses. These solutions are applied to the futuristic case of space rescue missions performed from the Space Station by the Orbital Maneuvering Vehicle. Author

A89-17641*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
TECHNOLOGY REQUIREMENTS FOR AN ORBITING FUEL DEPOT - A NECESSARY ELEMENT OF A SPACE INFRASTRUCTURE
R. M. STUBBS, R. R. CORBAN (NASA, Lewis Research Center, Cleveland, OH), and A. J. WILLOUGHBY (Analex Corp., Cleveland, OH) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 9 p. Previously announced in STAR as N88-29845. refs
(IAF PAPER 88-035)

Advanced planning within NASA has identified several bold space exploration initiatives. The successful implementation of these missions will require a supporting space infrastructure which would include a fuel depot, an orbiting facility to store, transfer and process large quantities of cryogenic fluids. In order to adequately plan the technology development programs required to enable the construction and operation of a fuel depot, a multidisciplinary workshop was convened to assess critical technologies and their state of maturity. Since technology requirements depend strongly on the depot design assumptions, several depot concepts are presented with their effect of criticality ratings. Over 70 depot-related technology areas are addressed. Author

A89-17712#
ISSUES ASSOCIATED WITH A FUTURE ORBIT TRANSFER VEHICLE (OTV)
EDWARD L. BANGSUND and ELDON E. DAVIS (Boeing Aerospace Co., Kent, WA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 6 p.
(IAF PAPER 88-185)

This paper reports on a NASA-sponsored study which reexamined issues connected with payload and duration requirements of manned missions planned for the 1990s. A manned Mars mission is emphasized, showing its impact on requirements regarding stage propellant capacity, stage thrust level, and propellant storage. Cryostage concepts for the STS are also considered. C.D.

A89-17765#
ANALYTICAL FORMULATION FOR FINITE-THRUST RENDEZVOUS TRAJECTORIES
JOZEF C. VAN DER HA (ESA, European Space Operations Centre, Darmstadt, Federal Republic of Germany) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 18 p. refs
(IAF PAPER 88-308)

Extensions to the classical Clohessy-Wiltshire (1960) orbital rendezvous conditions are presented. Whereas the Clohessy-Wiltshire rendezvous provides the instantaneous velocity impulses required for establishing rendezvous after a specified interval, the extensions analyzed here are the following: (1) the constant finite-thrust levels required for rendezvous after a specified interval are calculated, and (2) the classical impulsive Clohessy-Wiltshire rendezvous conditions are generalized in order to incorporate constant perturbing or thrust forces over the specified rendezvous interval. Finally, an analytical solution to a finite-thrust optimal rendezvous problem is presented. Author

A89-26775* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
ORBITAL MANEUVERING VEHICLE SPACE STATION COMMUNICATIONS DESIGN
D. ARNDT, S. W. NOVOSAD (NASA, Johnson Space Center, Houston, TX), K. TU, Y. C. LOH, and Y. S. KUO IN: GLOBECOM '88 - IEEE Global Telecommunications Conference and Exhibition, Hollywood, FL, Nov. 28-Dec. 1, 1988, Conference Record. Volume 3. New York, Institute of Electrical and Electronics Engineers, Inc., 1988, p. 1747-1751. refs

The authors present an Orbital Maneuvering Vehicle space station communications systems design approach which is intended to satisfy the stringent link requirements. The operational scenario, system configuration, signal design, antenna system management, and link performance analysis are discussed in detail. It is shown that the return link can transmit up to 21.6 Mb/s and maintain at least a 3-dB link margin through proper power and antenna management control at a maximum distance of 37 km. It is suggested that the proposed system, which is compatible with the space station multiple-access system, can be a model for other space station interoperating elements or users to save the development cost and reduce the technical and schedule risks. I.E.

A89-29246
SPACE-VEHICLE TRAJECTORIES - OPTIMIZATION
J. P. MAREC ONERA, TP, no. 1988-83, 1988, 11 p. refs
(ONERA, TP NO. 1988-83)

The application of control-theory optimization techniques to the motion of powered vehicles in space is discussed in an analytical review. Problems addressed include the definition of optimal orbital transfer; propulsion-system modeling; parametric optimization and the Hohmann transfer; optimal transfer in general, uniform, and central gravitational fields; and interplanetary rendezvous. Typical numerical results are presented in graphs and briefly characterized. T.K.

N89-15927*# Old Dominion Univ., Norfolk, VA. Dept. of Electrical and Computer Engineering.
GUIDANCE AND CONTROL STRATEGIES FOR AEROSPACE VEHICLES Progress Report, 1 Jul. - 31 Dec. 1988
DESINENI S. NAIDU and JOSEPH L. HIBEY Jan. 1989 41 p
(Contract NAG1-736)
(NASA-CR-182339; NAS 1.26:182339) Avail: NTIS HC A03/MF A01 CSCL 01/3

The optimal control problem arising in coplanar orbital transfer employing aeroassist technology and the fuel-optimal control problem arising in orbital transfer vehicles employing aeroassist technology are addressed. B.G.

N89-18505*# Martin Marietta Corp., Denver, CO. Astronautics Group.
ORBITAL TRANSFER VEHICLE CONCEPT DEFINITION AND SYSTEMS ANALYSIS STUDY. VOLUME 11: STUDY EXTENSION 2 RESULTS Final Report, Jan. 1987 - Jan. 1988
W. H. WILLCOCKSON Jan. 1988 165 p Revised
(Contract NAS8-36108)
(NASA-CR-184674; NAS 1.26:184674;
MCR-86-2601-VOL-11-REV) Avail: NTIS HC A08/MF A01 CSCL 22/2

Work conducted in the second extension of the Phase A Orbit Transfer Vehicle Concept Definition and Systems Analysis Study is summarized. Four major tasks were identified: (1) define an initial OTV program consistent with near term Civil Space Leadership Initiative missions; (2) develop program evolution to long term advanced missions; (3) investigate the implications of current STS safety policy on an Aft Cargo Carrier based OTV; and (4) expand the analysis of high entry velocity aeroassist. An increased emphasis on the breath of OTV applications was undertaken to show the need for the program on the basis of the expansion of the nation's capabilities in space. Author

N89-18518*# Ball Aerospace Systems Div., Boulder, CO.
SUPERFLUID HELIUM TANKER (SFHT) STUDY
1 Oct. 1988 157 p
(Contract NAS9-17852)
(NASA-CR-172116; NAS 1.26:172116; F88-04) Avail: NTIS HC A08/MF A01 CSCL 22/2

The accomplishments and recommendations of the two-phase Superfluid Helium Tanker (SFHT) study are presented. During the first phase of the study, the emphasis was on defining a

comprehensive set of user requirements, establishing SFHT interface parameters and design requirements, and selecting a fluid subsystem design concept. During the second phase, an overall system design concept was constructed based on appropriate analyses and more detailed definition of requirements. Modifications needed to extend the baseline for use with cryogens other than SFHT have been determined, and technology development needs related to the recommended design have been assessed. NASA

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LIFE SCIENCES/HUMAN FACTORS/SAFETY

Includes studies, models, planning, analyses and simulations for biological and medical laboratories, habitability issues for the performance and well-being of the crew, and crew rescue.

A89-10454
SPACE STATION EMERGENCY EGRESS AND EVA LIGHTING CONSIDERATIONS AND CANDIDATE KOCH HARDWARE
H. GERALD GROSS (Wickes Manufacturing Co., Anaheim, CA) IN: SAFE Association, Annual Symposium, 25th, Las Vegas, NV, Nov. 16-19, 1987, Proceedings. Newhall, CA, SAFE Association, 1987, p. 22-28.

The advantages of certain features of newly developed lighting devices and systems for Space Station internal emergencies, and normal and emergency EVA lighting, particularly for adverse optical conditions, are discussed. All that has been learned and developed for aircraft and helicopter egress scenarios is shown to have direct applicability to Space Station scenarios. The unique advantages of LED lighting devices and systems include very low power, very low voltage, low current, and very low weight. K.K.

A89-10587* RCA Government Services, Houston, TX.
PHYSIOLOGICAL ADAPTATION - CREW HEALTH IN SPACE
SUSAN BRAND (RCA, Government Services Div., Houston, TX) IN: Aerospace Behavioral Engineering Technology Conference, 6th, Long Beach, CA, Oct. 5-8, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 93-96. refs
(Contract NAS9-17133)
(SAE PAPER 871872)

The experiments planned for the Spacelab Life Sciences-1 (SLS-1) Shuttle mission, which is dedicated to investigating biomedical issues pertinent to the man's presence in space, are discussed. The areas of research will include human and animal experiments concerned with the cardiovascular system, the vestibular apparatus, and metabolic experiments related to renal endocrine function, hematology, immune system, and muscle and bone/calcium metabolism, with particular attention given to the physiological complications resulting from short-duration space flight and subsequent return to the 1-G environment. The hardware systems to be used on the SLS-1 mission represent prototypes of systems to be developed for the medical and research facilities of the Space Station. The results of the experiments will be used to address issues related to long-duration space flight required for the Space Station and interplanetary travels. I.S.

A89-14856
DINING IN THE STARS
BETTY NOLLEY Space World (ISSN 0038-6332), vol. Y-11-299, Nov. 1988, p. 13-16.

The process of food service planning for the Space Station is examined. The preparation of food aboard the Station, methods for keeping food fresh for long periods of time, and alternatives to dehydrated food are considered. Taste tests, menu selection, and the food served on the Space Shuttle are discussed and sample menus are presented. R.B.

A89-17835*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
MEDICAL CONSIDERATIONS FOR EXTENDING HUMAN PRESENCE IN SPACE
C. S. LEACH, L. F. DIETLEIN, S. L. POOL, and A. E. T. NICOGOSSIAN (NASA, Johnson Space Center, Houston, TX) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 9 p. refs
(IAF PAPER 88-484)

The medical factors affecting the duration of manned space missions are reviewed. Topics addressed include the effects of weightlessness on body fluids, the cardiovascular system, red blood cells, the musculoskeletal system, the immune system, and the nervous system and the problems encountered in readaptation to normal gravity for each of these systems. Also discussed are the effects of radiation exposure, altered circadian rhythms, and closed environments. Plans for in-flight health care on the International Space Station are briefly outlined. T.K.

A89-19857#
ANALYSIS OF HUMAN ACTIVITIES DURING SPACE MISSIONS - OUTLINES OF POSSIBLE HUMAN MISSIONS ABOARD COLUMBUS
ALAIN ESTERLE and ANTONIO GUELL (CNES, Paris, France) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 8 p. refs
(IAF PAPER 88-487)

The challenge to Europe posed by man in space is discussed. His activities in space are divided into the following: sleep, habitability, nutrition and hygiene, leisure, and work. Main medical and physiological constraints related to long-duration flights are outlined. K.K.

A89-23265
ASTRONAUT RADIATION - WILL IT BECOME A PROBLEM?
IAN PARKER Space (ISSN 0267-954X), vol. 4, May-June 1988, p. 30, 31, 33.

A 30-year-old male astronaut embarking on a NASA Space Station career encompassing six 180-day tours of duty over the course of six years will receive as much as 1800 millisieverts, or nearly as large a dose of radiation as is deemed permissible for a terrestrial worker over the course of an entire working life. Comparable severe radiation dosages will be experienced by astronauts over the three years of a Mars mission. It is noted that, in the case of far-future interstellar missions whose manned spacecraft speed exceeds about 5 percent the speed of light for substantial portions of the journey, collisions with interstellar gas will create nuclear reactions that generate gamma rays and neutrons at lethal doses; novel shielding methods will have to be developed for these extreme conditions. O.C.

A89-24375* Johns Hopkins Univ., Baltimore, MD.
DEPLOYING AND TESTING AN EXPANDABLE SURGICAL CHAMBER IN MICROGRAVITY
SANFORD M. MARKHAM and JOHN A. ROCK (Johns Hopkins Hospital, Baltimore, MD) Aviation, Space, and Environmental Medicine (ISSN 0095-6562), vol. 60, Jan. 1989, p. 76-79. Research supported by NASA. refs

Prolonged spaceflights will increase the possibility of injury to flight crews and mission personnel. These injuries are anticipated to include foreign body injury, mechanical injury, and burns. Surgical repair of these injuries must take into consideration problems of contamination of the injury as well as contamination of the Space Station or transport vehicle environment. Use of a portable expandable surgical chamber is felt to be the most efficient and effective means of providing necessary surgical care in a Space Station environment. A first prototype expandable surgical chamber has been developed and tested in zero gravity. A second prototype has now been developed and will be tested. Author

A89-24844
SPACE SAFETY AND RESCUE 1986-1987
GLORIA W. HEATH, ED. (SAR-ASSIST, Greenwich, CT) San

Diego, CA, Univelt, Inc. (Science and Technology Series. Volume 70), 1988, 357 p. For individual items see A89-24845 to A89-24850.

Technological and policy aspects of space safety, space rescue, and space-based terrestrial rescue systems are discussed in reviews and reports. Topics addressed include safety and rescue (S&R) evaluations of planned space stations, human factors on the International Space Station, the decay of trackable space objects, and orbital-debris hazard mitigation using the OMV. Consideration is given to satellite communication in land disasters, S&R considerations for space biological experiments, crew rescue equipment for manned space missions, S&R planning for Hermes, and the breakup of the Cosmos 1275 satellite. T.K.

A89-24845
RISK ASSESSMENT FOR SAFETY
CHARLES R. HADLOCK and PETER E. GLASER (Arthur D. Little, Inc., Cambridge, MA) IN: Space safety and rescue 1986-1987. San Diego, CA, Univelt, Inc., 1988, p. 11-16. refs
(IAF PAPER 86-59B)

The application of probabilistic risk-assessment techniques to space missions is discussed, with a focus on the International Space Station. The types of hazards likely to be caused by random events; design, operational, and management errors; and intentional intervention are examined along with their secondary effects; and the top-level safety requirements defined by NASA are considered. It is suggested that such qualitative stipulations be supplemented with more quantitative measures such as used in the nuclear-power industry; the major features of such quantitative methods are reviewed. T.K.

A89-24847
SPACE STATION SAFETY PLANNING
FRANCIS X. KANE (Rockwell International Corp., El Segundo, CA) IN: Space safety and rescue 1986-1987. San Diego, CA, Univelt, Inc., 1988, p. 27-39. refs
(IAF PAPER 86-59E)

Planning strategies for the incorporation of safe havens in the design of the International Space Station are presented in extensive charts and diagrams and discussed. The haven is defined as an area in the Space Station where crew members could be safe from an external or internal hazard until rescue could be effected. Consideration is given to the degree of safety required; the major external and internal threats; specific strategies for fire, material control, contamination, injury or illness, depressurization, meteoroids, and radiation; escape and rescue options; and alternative measures. T.K.

A89-26650* Utah Univ., Salt Lake City.
A PROTOTYPE GAS EXCHANGE MONITOR FOR EXERCISE STRESS TESTING ABOARD NASA SPACE STATION
JOSEPH A. ORR, DWAYNE R. WESTENSKOW, and ANNE BAUER (Utah, University, Salt Lake City) Journal of Applied Physiology (ISSN 0161-7567), vol. 66, Jan. 1989, p. 492-497. Research supported by Krug International Corp. refs
(Contract NAS9-17345)

This paper describes an easy-to-use monitor developed to track the weightlessness deconditioning aboard the NASA Space Station, together with the results of testing of a prototype instrument. The monitor measures the O2 uptake and CO2 production, and calculates the maximum O2 uptake and anaerobic threshold during an exercise stress test. The system uses two flowmeters in series to achieve a completely automatic calibration, and uses breath-by-breath compensation for sample line-transport delay. The monitor was evaluated using two laboratory methods and was shown to be accurate. The system's block diagram and the bench test setup diagram are included. I.S.

A89-27813* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SPACE MEDICINE
SAM L. POOL (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 7 p.
(SAE PAPER 881009)

This paper attempts to underscore the importance of continued studies on the effects of space on human physiology. With particular reference to the Space Station, it is pointed out that there are two aspects which are challenging to life scientists: first is the development of a research capability for the life sciences which will be used to conduct investigations necessary to extend the time humans can remain in space; second is the challenge to develop a medical capability to provide prevention, diagnosis, and therapy. A discussion of physiological changes that have been observed in spacecrews follows along the lines of the two aspects mentioned. S.A.V.

A89-27815* National Aeronautics and Space Administration, Washington, DC.
LIFE SCIENCES - ON THE CRITICAL PATH FOR MISSIONS OF EXPLORATION
FRANK M. SULZMAN, MARY M. CONNORS (NASA, Washington, DC), and KAREN GAISER (Lockheed Engineering and Sciences Co., Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 11 p. refs
(SAE PAPER 881012)

Life sciences are important and critical to the safety and success of manned and long-duration space missions. The life science issues covered include gravitational physiology, space radiation, medical care delivery, environmental maintenance, bioregenerative systems, crew and human factors within and outside the spacecraft. The history of the role of life sciences in the space program is traced from the Apollo era, through the Skylab era to the Space Shuttle era. The life science issues of the space station program and manned missions to the moon and Mars are covered. A.A.F.

A89-27816* National Aeronautics and Space Administration, Washington, DC.
TECHNOLOGY FOR HUMAN SELF-SUFFICIENCY IN SPACE
JOHN L. ANDERSON (NASA, Washington, DC) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 10 p.
(SAE PAPER 881013)

A proposed Pathfinder program would determine the critical human and technology requirements for human self-sufficiency and productivity on manned and long-duration missions to the moon and Mars. Human health would require countermeasures against weightlessness, protection from space radiation and habitats conducive to psychological well-being. Life support systems would need regeneration of expendable resources, power systems for plant life support and processing; and microbial contaminant control. Operational performance requirements include extravehicular activites suit, interactive systems for shared control between humans and computers, and human-centered semi-autonomous systems. A.A.F.

A89-27827
CONCEPTS FOR CREW EXPERIMENT INTERACTION - FUTURE SPACE FLIGHTS: WORKSTATION DESIGN AND REQUIREMENTS
BYRON K. LICHTENBERG (Payload Systems, Inc., Wellesley, MA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 5 p.
(SAE PAPER 881025)

Concepts and requirements for future workstations and capabilities that should be inherent in the next generation of spacecraft are discussed. The future workstation should be flexible to accommodate new processors and links to new or modified networks and conform to industry-accepted standards. It should support automation and possibly artificial intelligence and should have the capability to process and display both digital and video/text information. The system should be able to access data, to control experiments, and to communicate with ground scientists from any location aboard the spacecraft. C.D.

A89-27831* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
AN ARTIFICIAL GRAVITY RESEARCH FACILITY FOR LIFE SCIENCES
LARRY G. LEMKE (NASA, Ames Research Center, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 14 p. refs
(SAE PAPER 881029)

To obtain data for the design of a Mars mission vehicle configured for artificial gravity, NASA is currently studying the design of a variable-gravity research facility (VGRF) in a low earth orbit. The VGRF could be flown as a coorbiting payload requiring periodic servicing, resupply, and contingency intervention from the Space Station. The reasons why artificial gravity is needed for long-term missions are discussed; preliminary designs of a Mars vehicle with artificial gravity (at a weight cost of about 20 percent) are described; and particular attention is given to the VGRF design and mission profile. A.A.F.

A89-27848
ROLE OF GNOTOBIOTICS IN A SPACE STATION
RALPH BAKER (Colorado State University, Fort Collins) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 6 p. refs
(SAE PAPER 881048)

In covered structures and semiclosed ecological systems on earth, disease epidemics occur frequently because pathogens can spread so rapidly. Chemical pesticides greatly reduce epidemics but alternative measures are needed for space applications. Two strategies for control are exclusion and sanitation procedures to prevent invasion of deleterious microorganisms and gnotobiotic infestation with organisms that act both as biological control agents and as plant growth promoters. Author

A89-27849* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
BIOISOLATION ON THE SPACE STATION
SJOERD L. BONTING, ROGER D. ARNO, JENNY S. KISHIYAMA, and CATHERINE C. JOHNSON (NASA, Ames Research Center, Moffett Field, CA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 8 p. refs
(SAE PAPER 881050)

Animal research on the Space Station presents the need for bioisolation, which is here defined as instrumental and operational provisions, which will prevent the exchange of particles greater than 0.3-micron size and microorganisms between crew and animals. Current design principles for the Biological Research Project thus call for: (1) use of specific pathogen-free animals; (2) keeping animals at all times in enclosed habitats, provided with microbial filters and a waste collection system; (3) placing habitats in a holding rack, centrifuge, and workbench, all equipped with particulate and odor filters, (4) washing dirty cage units in an equipment cleaner, with treatment and recycling of the water; (5) designing components and facilities so as to ensure maximal accessibility for cleaning; and (6) defining suitable operational procedures. Limited ground tests of prototype components indicate that proper bioisolation can thus be achieved. Author

A89-27851
LOCAL RESOURCE UTILIZATION AND INTEGRATION INTO ADVANCED MISSION'S LSS
FEROLYN T. POWEL (Life Systems, Inc., Cleveland, OH) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 10 p. refs
(SAE PAPER 881053)

Key design drivers of the Life Support System (LSS) of advanced manned space missions are duration, distance from earth and cost. All drive the LSS design toward the elimination of expendables and resupply requirements (from earth). Local resource utilization will be required to completely eliminate resupply requirements from earth. Also, in some instances, it may be advantageous to utilize local resources instead of regenerative technologies. This paper provides an introduction and overview to local resource utilization related to the LSS of advanced missions. Author

A89-27867
OXYGEN TOXICITY DURING FIVE SIMULATED EIGHT-HOUR EVA EXPOSURES TO 100 PERCENT OXYGEN AT 9.5 PSIA
J. T. WEBB, R. M. OLSON, R. W. KRUTZ, JR. (Krug International, San Antonio, TX), G. A. DIXON, and P. T. BARNICOTT (USAF, School of Aerospace Medicine, Brooks AFB, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 8 p. refs
(Contract F33615-85-C-4503)
(SAE PAPER 881071)

A study was conducted to determine if oxygen toxicity occurs in a proposed extravehicular activity (EVA) pressure suit environment. Twelve male subjects were exposed to 100 percent oxygen at 9.5 psia for five consecutive days, 8 h/day, while performing moderate exercise. No decompression sickness or venous gas bubbles were detected. Pulmonary function tests, physical exams, blood analyses, arterial oxygen saturation monitoring, and X-rays showed no evidence of oxygen toxicity. These results suggest that a 100 percent oxygen, 9.5 psia pressure suit environment could avoid both decompression sickness and oxygen toxicity during EVAs of comparable duration and physical activity. Author

A89-27871* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
LIFE SCIENCES SPACE BIOLOGY PROJECT PLANNING
G. PRIMEAUX, K. NEWKIRK, L. MILLER (NASA, Johnson Space Center, Houston, TX), G. LEWIS, R. MICHAUD et al. SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 8 p. refs
(SAE PAPER 881075)

The Life Sciences Space Biology (LSSB) research will explore the effect of microgravity on humans, including the physiological, clinical, and sociological implications of space flight and the readaptations upon return to earth. Physiological anomalies from past U.S. space flights will be used in planning the LSSB project.The planning effort integrates science and engineering. Other goals of the LSSB project include the provision of macroscopic view of the earth's biosphere, and the development of spinoff technology for application on earth. A.A.F.

A89-27875* Leeds and Northrup Co., North Wales, PA.
OXYGEN SENSOR OPTIMIZATION FOR LONG DURATION SPACE MISSIONS
R. M. TAYLOR, E. S. VAN VALKENBURG (Leeds and Northrup Co., North Wales, PA), and R. J. CUSICK (NASA, Johnson Space Center, Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 8 p.
(SAE PAPER 881079)

A new type of oxygen sensor is being developed for potential use in future manned space missions. This sensor incorporates two independent measurement schemes using dual electrochemical cells formed in a common body of solid electrolyte-zirconia. A combination of potentiometric and coulometric measurements yields accurate and fast response to cabin atmosphere oxygen. Means for self-calibration, fault detection and diagnosis by computer operation are discussed. Author

A89-27876* Astro International Corp., Houston, TX.
NEW ADVANCES IN NON-DISPERSIVE IR TECHNOLOGY FOR CO2 DETECTION
JOHN W. SMALL and WAYNE L. ODEGARD (Astro International Corp., Houston, TX) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 6 p. refs
(Contract NAS9-17612)
(SAE PAPER 881080)

This paper discusses new technology developments in CO2 detection using Non-Dispersive Infrared (NDIR) techniques. The

method described has successfully been used in various applications and environments. It has exhibited extremely reliable long-term stability without the need of routine calibration. The analysis employs a dual wavelength, differential detection approach with compensating circuitry for component aging and dirt accumulation on optical surfaces. The instrument fails 'safe' and provides the operator with a 'fault' alarm in the event of a system failure. The NDIR analyzer described has been adapted to NASA Space Station requirements. Author

A89-27884
APPLICATIONS OF MAN-SYSTEMS INTEGRATION STANDARDS TO EVA
CHARLES W. GEER (Boeing Aerospace, Seattle, WA) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 9 p.
(SAE PAPER 881089)

The NASA Man-Systems Integration Standards (MSIS) are examined, focusing on the implications of the standards for EVA and human engineering. The process used to develop these standards and the MSIS documents and data base are described. The discussion of EVA design considerations and requirements in the MSIS documents is reviewed, including physiology, anthropometry, workstations and restraints, mobility and translation, enhancement systems, and tools, fasteners, and connectors. Also, the distribution, implementation, and maintenance of the standards are considered. R.B.

A89-27890
BIOSPHERE II - DESIGN OF A CLOSED, MANNED TERRESTRIAL ECOSYSTEM
WILLIAM F. DEMPSTER (Space Biospheres Ventures, Oracle, AZ) SAE, Intersociety Conference on Environmental Systems, 18th, San Francisco, CA, July 11-13, 1988. 8 p.
(SAE PAPER 881096)

The habitat designated 'BIOSPHERE II' (the planet earth being BIOSPHERE I), which is currently under construction in the Arizona desert and due for completion in January, 1990, will be a stable, but complex and evolving, closed ecosystem encompassing seven distinct biomes covering 2.25 acres of floor area. The seven biomes are tropical rain forest, tropical savannah, marsh, marine, desert, intensive agriculture, and human habitat. The lessons learned from the design and operation of BIOSPHERE II are potentially applicable to refuges for endangered species, interstellar spacecraft, space stations, and other-planet human habitats. O.C.

A89-28422#
LIFE SCIENCES USES OF SPACE STATION FREEDOM
LAURENCE R. YOUNG (MIT, Cambridge, MA) and C. E. RUDIGER, JR. (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 7 p. refs
(AIAA PAPER 89-0509)

The outfitting and payloads of the pressurized life sciences research laboratories on the Space Station are presented. The determination of the limits of human tolerance to extended weightlessness and the development and testing of methods to counteract the effects of weightlessness are reviewed. The study of gravitational biology and the use of partially closed life support systems to minimize the requirements for logistic resupply missions are discussed. The major life science facilities on the Space Station are described, including the laboratory support facilities and equipment, the 1.8-meter centrifuge, and human research equipment. Possible solutions to limitations and interface issues pertaining to the life sciences are examined, including issues such as vibration and acceleration, bioisolation, rapid access to samples, operational flexibility, and volume limitations. R.B.

A89-31601
HUMAN FACTORS SOCIETY, ANNUAL MEETING, 32ND, ANAHEIM, CA, OCT. 24-28, 1988. PROCEEDINGS. VOLUMES 1 & 2
Meeting sponsored by the Human Factors Society. Santa Monica, CA, Human Factors Society, 1988, p. Vol. 1, 768 p.; vol. 2, 784 p. For individual items see A89-31602 to A89-31678.

Papers dealing with human factors in transportation are presented, covering topics such as pilot performance and simulation, Space Station design and performance, human factors design in special-purpose workstations for the Space Station, auditory spatial information and head-coupled display systems, situation awareness in aircraft systems, control and display issues, human factors in maintenance, aging, telephony and video teleconferencing, auditory and vocal communication, and aircrew station workload, design, and automation. Other subjects include approaches to user interface design, speech recognition systems, hypermedia and interfaces, the development of documentation in real time, computer screen and menu design, expert systems, human factors education, design of work environments, forensics issues, human factors and automobiles, industrial ergonomics, international technology transfer, organizational design and management, personality and human performance, mental models of complex performance, and gender, intelligence, and human performance. Additional topics include accident analysis, product safety, transportation safety, robotics/industrial safety, system development, the human-computer interface, human factors in navy systems, workload evaluation, training systems and data bases, skill aquisition, visual performance, information portrayal determinants of complex decision making, and advanced displays. R.B.

A89-31606
AMERICAN AND JAPANESE CONTROL-DISPLAY STEREOTYPES - POSSIBLE IMPLICATIONS FOR DESIGN OF SPACE STATION SYSTEMS
CLIFFORD K. WONG and JOHN LYMAN (California, University, Los Angeles) IN: Human Factors Society, Annual Meeting, 32nd, Anaheim, CA, Oct. 24-28, 1988, Proceedings. Volume 1. Santa Monica, CA, Human Factors Society, 1988, p. 30-34. refs

The stimulus-response stereotypes of American and Japanese subjects are tested to aid in the determination of guidelines for the design of control-display systems for the Space Station. A set of 24 display configurations were tested to determine the direction which people from the two cultures most frequently turn control knobs to accomplish a certain direction or motion of a pointer in a vertical display. Only one configuration elicited similar and statistically significant reponse stereotypes from both groups. It is shown that the optimal configuration should have the control knob on the right side of the display and the numerical scale on the side of the display opposite to the control knob, with the display pointer pointing away from the knob and the scale markings increasing from bottom to top. R.B.

A89-31607
FORECASTING CREW ANTHROPOMETRY FOR SHUTTLE AND SPACE STATION
JOHN ROEBUCK (Roebuck Research and Consulting, Santa Monica, CA), KIM SMITH, and LOUIS RAGGIO (Rockwell International Corp., Downey, CA) IN: Human Factors Society, Annual Meeting, 32nd, Anaheim, CA, Oct. 24-28, 1988, Proceedings. Volume 1. Santa Monica, CA, Human Factors Society, 1988, p. 35-39. refs

Habitation module and Crew Emergency Rescue Vehicle (CERV) designs for the International Space Station to be built by the United States are expected to accommodate a wide range of persons, according to body dimensions predicted for the year 2000. This prediction was aided by the opportunity, which arose in 1985, to check actual Space Shuttle male crew anthropometry, particularly stature, against predictions made circa 1973 and by recently acquired Japanese data. Revised hypotheses discussed herein have been accepted by an Anthropometry Working Group as the bases for developing anthropometry requirements that appear in the Man-Systems Integration Standard (NASA-STD-3000), published in 1987. Pleas are made for further research in civilian anthropometry and wider use of anthropometric forecasting. Author

N89-10111*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FIRE BEHAVIOR AND RISK ANALYSIS IN SPACECRAFT
ROBERT FRIEDMAN and KURT R. SACKSTEDER 1988 14 p Prepared for presentation at the Winter Annual Meeting of the American Society of Mechanical Engineers, Chicago, Ill., 28 Nov. - 3 Dec. 1988
(NASA-TM-100944; E-4232; NAS 1.15:100944) Avail: NTIS HC A03/MF A01 CSCL 22B

Practical risk management for present and future spacecraft, including space stations, involves the optimization of residual risks balanced by the spacecraft operational, technological, and economic limitations. Spacecraft fire safety is approached through three strategies, in order of risk: (1) control of fire-causing elements, through exclusion of flammable materials for example; (2) response to incipient fires through detection and alarm; and (3) recovery of normal conditions through extinguishment and cleanup. Present understanding of combustion in low gravity is that, compared to normal gravity behavior, fire hazards may be reduced by the absence of buoyant gas flows yet at the same time increased by ventilation flows and hot particle expulsion. This paper discusses the application of low-gravity combustion knowledge and appropriate aircraft analogies to fire detection, fire fighting, and fire-safety decisions for eventual fire-risk management and optimization in spacecraft. Author

N89-10522*# National Aeronautics and Space Administration, Washington, DC.
LIVING IN SPACE, BOOK 2, LEVELS D, E, F
SHEILA BRISKIN ANDREWS and AUDREY KIRSCHENBAUM 1987 70 p Original document contains color illustrations
(NASA-EP-223; NAS 1.19:223) Avail: SOD HC $4.75 as 033-000-01001; NTIS MF A01 CSCL 06K

In June 1984, President Reagan announced a new NASA program, Operation Liftoff. For more than 25 years NASA has pioneered on the cutting edge of science and technology and has stimulated our young people to strive for excellence in all they do. This program is designed to encourage pupils in the nation's elementary schools to take a greater interest in mathematics and science. Areas addressed include: food, clothing, health, housing, communication, and working in space. B.G.

N89-11764*# National Aeronautics and Space Administration, Washington, DC.
PATHFINDER: HUMANS IN SPACE
JOHN L. ANDERSON *In its* Technology for Future NASA Missions: Civil Space Technology Initiative (CSTI) and Pathfinder p 93-106 Sep. 1988
Avail: NTIS HC A23/MF A01 CSCL 22/1

Viewgraphs are presented on the Pathfinder program. Information is given on human exploration of the solar system, technical requirements interfaces, program objectives, space suits, human performance, man-machine systems, space habitats, life support systems, and artificial gravity R.J.F.

N89-11772*# National Aeronautics and Space Administration, Washington, DC.
INFORMATION SCIENCES AND HUMAN FACTORS OVERVIEW
LEE B. HOLCOMB *In its* Technology for Future NASA Missions: Civil Space Technology Initiative (CSTI) and Pathfinder p 231-245 Sep. 1988
Avail: NTIS HC A23/MF A01 CSCL 22/1

An overview of program objectives of the Information Sciences and Human Factors Division of NASA's Office of Aeronautics and Space Technology is given in viewgraph form. Information is given on the organizational structure, goals, the research and technology base, telerobotics, systems autonomy in space operations, space sensors, humans in space, space communications, space data systems, transportation vehicle guidance and control, spacecraft control, and major program directions in space. R.J.F.

N89-12583*# Jet Propulsion Lab., California Inst. of Tech., Pasadena.
WF/PC INTERNAL MOLECULAR CONTAMINATION DURING SYSTEM THERMAL-VACUUM TEST
DANIEL M. TAYLOR, J. BARENGOLTZ, T. JENKINS, K. LESCHLY, and J. TRIOLO *In* NASA, Goddard Space Flight Center, 15th Space Simulation Conference: Support the Highway to Space Through Testing p 1-10 1988
Avail: NTIS HC A21/MF A01 CSCL 14/2

During the recent system thermal vacuum test of the Wide-Field/Planetary Camera (WF/PC), instrumentation was added to the WF/PC to characterize the internal molecular contamination and verify the instrument throughput down to 1470 angstroms. Analysis of data elements revealed two contaminants affecting the far-ultraviolet (FUV) performance of the WF/PC. The one contaminant (heavy volatile) is correlated with the electronic and housing temperature, and the contamination is significantly reduced when the electronics are operated below plus 8 degrees to plus 10 degrees C. The other contaminant (light volatile) is controlled by the heat pipe temperature, and the contamination is significantly reduced when the Thermal Electric Cooler (TEC) hot-junction temperature is below minus 40 degrees to minus 50 degrees C. The utility of contamination sensors located behind instruments during system tests was demonstrated. Author

N89-15017*# National Aeronautics and Space Administration, Washington, DC.
EXOBIOLOGY EXPERIMENT CONCEPTS FOR SPACE STATION Abstract Only
LYNN D. GRIFFITHS (Management and Technical Services Co., Washington, DC.) and DONALD L. DEVINCENZI *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 1 p Nov. 1987 Previously announced as N86-27152
Avail: NTIS HC A09/MF A01 CSCL 06/3

The exobiology discipline uses ground based and space flight resources to conduct a multidiscipline research effort dedicated to understanding fundamental questions about the origin, evolution, and distribution of life and life related molecules throughout the universe. Achievement of this understanding requires a methodical research strategy which traces the history of the biogenic elements from their origins in stellar formation processes through the chemical evolution of molecules essential for life to the origin and evolution of primitive and, ultimately, complex living species. Implementation of this strategy requires the collection and integration of data from solar system exploration spacecraft and ground based and orbiting observatories and laboratories. The Science Lab Module (SLM) of the Space Station orbiting complex may provide an ideal setting in which to perform certain classes of experiments which form the cornerstone of exobiology research. These experiments could demonstrate the pathways and processes by which biomolecules are synthesized under conditions that stimulate the primitive earth, planetary atmospheres, cometary ices, and interstellar dust grains. Exobiology experiments proposed for the Space Station generally fall into four classes: interactions among gases and grains (nucleation, accretion, gas-grain reactions), high energy chemistry for the production of biomolecules, physical and chemical processes occurring on an artificial comet, and tests of the theory of panspermia. Author

N89-15505*# Alabama Univ., Huntsville. Consortium for the Space Life Sciences.
ENVIRONMENTAL CONTROL MEDICAL SUPPORT TEAM Final Report
WILLIAM J. CRUMP and MELVIN V. KILGORE, JR. Oct. 1988 430 p
(Contract NAG8-698)
(NASA-CR-184619; NAS 1.26:184619; UAH-RR-742) Avail: NTIS HC A19/MF A01 CSCL 06/3

The activities conducted in support of the Environmental Control and Life Support Team during December 7, 1987 through September 30, 1988 are summarized. The majority of the ongoing support has focused on the ECLSS area. Through a series of

initial meetings with the ECLSS team and technical literature review, an initial list of critical topics was developed. Subtasks were then identified or additional related tasks received as action items from the ECLSS group meetings. Although most of the efforts focused on providing MSFC personnel with information regarding specific questions and problems related to ECLSS issues, other efforts regarding identifying an ECLSS Medical Support Team and constructing data bases of technical information were also initiated and completed. The specific tasks are as follows: (1) Provide support to the mechanical design and integration of test systems as related to microbiological concerns; (2) Assist with design of Human Subjects Test Protocols; (3) Interpretation and recommendations pertaining to air/water quality requirements; (4) Assist in determining the design specifications required as related to the Technical Demonstration Program; (5) Develop a data base of all microorganisms recovered from previous subsystem testing; (6) Estimates of health risk of individual microbes to test subjects; (7) Assist with setting limits for safety of test subjects; (8) Health monitoring of test subjects; (9) Assist in the preparation of test plans; (10) Assist in the development of a QA/QC program to assure the validity, accuracy and precision of the analyses; and (11) Assist in developing test plans required for future man in the loop testing. Author

N89-17392*# Grumman Aerospace Corp., Bethpage, NY. Space Systems.

EXTRAVEHICULAR ACTIVITIES LIMITATIONS STUDY. VOLUME 1: PHYSIOLOGICAL LIMITATIONS TO EXTRAVEHICULAR ACTIVITY IN SPACE Final Report

PAUL A. FURR, CONRAD B. MONSON, ROBERT L. SANTORO, WILLIAM J. SEARS, DONALD H. PETERSON, and MALCOLM SMITH (ILC Space Systems, Dover, DE.) 1988 269 p
(Contract NAS9-17702)
(NASA-CR-172098; NAS 1.26:172098; AS-EVALS-FR-8701-VOL-1) Avail: NTIS HC A12/MF A01 CSCL 06/19

This report contains the results of a comprehensive literature search on physiological aspects of EVA. Specifically, the topics covered are: (1) Oxygen levels; (2) Optimum EVA work; (3) Food and Water; (4) Carbon dioxide levels; (5) Repetitive decompressions; (6) Thermal, and (7) Urine collection. The literature was assessed on each of these topics, followed by statements on conclusions and recommended future research needs. Author

N89-17404*# Texas A&M Univ., College Station. The Regenerative Concepts Team.

REGENERATIVE LIFE SUPPORT SYSTEM RESEARCH AND CONCEPTS Progress Report, Apr. - Dec. 1988

Dec. 1988 234 p
(Contract NAG9-253)
(NASA-CR-184760; NAS 1.26:184760; SRC-5-5873-3) Avail: NTIS HC A11/MF A01 CSCL 06/11

Life support systems that involve recycling of atmospheres, water, food and waste are so complex that models incorporating all the interactions and relationships are vital to design, development, simulations, and ultimately to control of space qualified systems. During early modeling studies, FORTRAN and BASIC programs were used to obtain numerical comparisons of the performance of different regenerative concepts. Recently, models were made by combining existing capabilities with expert systems to establish an Intelligent Design Support Environment for simpliflying user interfaces and to address the need for the engineering aspects. Progress was also made toward modeling and evaluating the operational aspects of closed loop life support systems using Time-step and Dynamic simulations over a period of time. Example models are presented which show the status and potential of developed modeling techniques. For instance, closed loop systems involving algae systeMs for atmospheric purification and food supply augmentation, plus models employing high plants and solid waste electrolysis are described and results of initial evaluations are presented. Author

N89-17996*# Massachusetts Inst. of Tech., Cambridge. Man-Vehicle Lab.

MIT-KSC SPACE LIFE SCIENCES TELESCIENCE TESTBED Final Technical Report

Feb. 1989 21 p
(Contract NAGW-1092)
(NASA-CR-184769; NAS 1.26:184769; OSP-99187) Avail: NTIS HC A03/MF A01 CSCL 06/3

A Telescience Life Sciences Testbed is being developed. The first phase of this effort consisted of defining the experiments to be performed, investigating the various possible means of communication between KSC and MIT, and developing software and hardware support. The experiments chosen were two vestibular sled experiments: a study of ocular torsion produced by Y axis linear acceleration, based on the Spacelab D-1 072 Vestibular Experiment performed pre- and post-flight at KSC; and an optokinetic nystagmus (OKN)/linear acceleration interaction experiment. These two experiments were meant to simulate actual experiments that might be performed on the Space Station and to be representative of space life sciences experiments in general in their use of crew time and communications resources. Author

N89-18379*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

LIVING AND WORKING IN SPACE

LINDA ARMSTRONG *In its* NASA Ames Summer High School Apprenticeship Research Program: 1986 Research Papers p 1-8 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 05/8

A brief overview is presented of the space station concept. Living conditions in space, space station design, and space logistics are briefly examined. E.R.

N89-18405*# National Aeronautics and Space Administration, Washington, DC.

HUMAN FACTORS: SPACE

JAMES P. JENKINS *In its* NASA Information Sciences and Human Factors Program p 179-201 Sep. 1988
Avail: NTIS HC A10/MF A01 CSCL 05/8

The objectives are to provide a technology base for intelligent operator interfaces, especially with autonomous subsystems, and to develop a new generation of high performance space suits, gloves, and tools/end effectors to meet the requirements of advanced space missions. The technology base is intended to meet the requirements of productivity, efficiency, and safety in complex manned operations within automated onboard systems and extravehicular activities (EVA) environments. Crew station research is the first of two major areas. Development of methods for the astronaut to supervise, monitor, and evaluate the performance of robotic systems, other space subsystems, and orbital vehicles are key areas of research. The second major area is development of an EVA space suit and gloves. Emphasis in the space human factors research program is placed on technology baseline studies and development of methods, techniques, and data to support productive and safe operations by the astronaut and crew as they interface with complex systems, advance automation, and robotic assistants. Author

N89-19861*# Lockheed Engineering and Sciences Co., Houston, TX.

SIMULATION OF THE HUMAN-TELEROBOT INTERFACE

MARK A. STUART and RANDY L. SMITH *In* NASA. Lyndon B. Johnson Space Center, 2nd Annual Workshop on Space Operations Automation and Robotics (SOAR 1988) p 321-326 Nov. 1988
(Contract NAS9-17900)
Avail: NTIS HC A22/MF A01 CSCL 05/8

A part of NASA's Space Station will be a Flight Telerobotic Servicer (FTS) used to help assemble, service, and maintain the Space Station. Since the human operator will be required to control the FTS, the design of the human-telerobot interface must be optimized from a human factors perspective. Simulation has been used as an aid in the development of complex systems. Simulation has been especially useful when it has been applied to the

development of complex systems. Simulation should ensure that the hardware and software components of the human-telerobot interface have been designed and selected so that the operator's capabilities and limitations have been accommodated for since this is a complex system where few direct comparisons to existent systems can be made. Three broad areas of the human-telerobot interface where simulation can be of assistance are described. The use of simulation not only can result in a well-designed human-telerobot interface, but also can be used to ensure that components have been selected to best meet system's goals, and for operator training. Author

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GENERAL

Includes descriptions, analyses, trade studies, commercial opportunities, published proceedings, seminars, hearings, historical summaries, policy speeches and statements that have not previously been included.

A89-10580
CURRENT MILITARY/GOVERNMENT APPLICATIONS FOR SPEECH RECOGNITION
JAMES W. HICKS, JR. (SCI Technology, Inc., Huntsville, AL) IN: Aerospace Behavioral Engineering Technology Conference, 6th, Long Beach, CA, Oct. 5-8, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 37-39.
(SAE PAPER 871750)

This paper presents an overview of several military/government programs in which SCI Technology has implemented and tested its speech recognition technology. Included are the Speckled Trout (U.S. Air Force), LHX (Light Helicopter Experimental, U.S. Army), Space Shuttle (NASA), Space Station, AFTI F-16, and ATF (Advanced Tactical Fighter) programs. Some of the programs consist of technology demonstrations, while others involve flight testing, and one, Speckled Trout, operationally installing and utilizing a system on a continual basis. In some cases, the hardware consists of an SCI Voice Control Unit (VCU-5137) and in others, a Voice Development System (VDS-7001). Author

A89-10628
FROM KITTY HAWK TO THE YEAR 2000
SAMUEL J. SMYTH IN: International Pacific Air and Space Technology Conference, Melbourne, Australia, Nov. 13-17, 1987, Proceedings. Warrendale, PA, Society of Automotive Engineers, Inc., 1988, p. 1-21. refs
(SAE PAPER 872395)

The evolution of aerospace vehicles is traced from the Wright Brother's first flights to a glimpse into the future. Some highlights of the discussion are the Fokker T-2, the DC-3, the Lockheed twin engines, VTOL, the Bell X-1, the Boeing 707, the Boeing 747, the Mercury project, the Mariner spacecraft, the Apollo program, Skylab, and the Space Shuttle. B.J.

A89-12102
COLLOQUIUM ON THE LAW OF OUTER SPACE, 30TH, BRIGHTON, ENGLAND, OCT. 10-17, 1987, PROCEEDINGS
Colloquium sponsored by the International Institute of Space Law of IAF. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 439 p. For individual items see A89-12103 to A89-12129.

National and international legal aspects of space exploration, militarization, and exploitation are examined from a wide range of perspectives. Topics addressed include the maintenance of outer space for peaceful purposes, space environmental problems, space commercialization, and the role of the UN in regulating remote-sensing activities. Consideration is given to mechanisms for improving international cooperation; the history of space law; the space implications of U.S. and Soviet doctrines on ABM, SALT II, SDI, and ASAT; man-made space debris and its control; space pollution; national space legislation in Europe; NASA and commercial ELV services; U.S. DOT regulations; equitable access to orbital and spectral resources; newsgathering from space; conflicts between national and international legislation on remote sensing; EEC regulations on international satellite communication; and COPUOS deliberations on nuclear power in space. T.K.

A89-12104*# National Aeronautics and Space Administration, Washington, DC.
MAINTAINING OUTER SPACE FOR PEACEFUL PURPOSES THROUGH INTERNATIONAL COOPERATION
GEORGE E. REESE, DAVID J. THACHER (NASA, Washington, DC), and HELEN S. KUPPERMAN IN: Colloquium on the Law of Outer Space, 30th, Brighton, England, Oct. 10-17, 1987, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 52-55. refs

NASA activities in support of international cooperation in space exploration and exploitation are briefly reviewed, with a focus on their compatibility with UN treaties. Particular attention is given to the provisions of the National Aeronautics and Space Act of 1958 and other applicable legislation, the over 1000 bilateral and international agreements NASA has entered into since 1958, international participation in currently ongoing NASA projects (Hubble Space Telescope, Galileo, Ulysses, Rosat, the D-2 Spacelab mission), and plans for the International Space Station. T.K.

A89-12106#
LEGAL ASPECTS OF ENVIRONMENTAL PROTECTION IN OUTER SPACE REGARDING DEBRIS
I. H. PH. DIEDERIKS-VERSCHOOR (International Institute of Space Law, Paris, France) IN: Colloquium on the Law of Outer Space, 30th, Brighton, England, Oct. 10-17, 1987, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, p. 131-134. refs

The problem of man-made space debris is considered from a legal perspective, reviewing the opinions expressed in recent international discussions. Topics examined include the applicable provisions of the Space Treaty of 1967, the Registration Treaty of 1975, and the Moon Agreement of 1979; the definition of a 'space object' in these treaties; the dangers posed to manned spacecraft by even small debris; and the need for more specific international regulations. The GEO communication satellites are shown to be the most likely to produce debris, and particular attention is given to the problem of wastes from manned space stations and the two main solutions proposed to deal with no-longer-functional spacecraft (destruction and removal to a safe space location). T.K.

A89-12175#
THE CIVIL SPACE PROGRAM: AN INVESTMENT IN AMERICA - AN AIAA POSITION PAPER
Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 3 p.

Arguments in favor of a strong civil space program are outlined. The benefits of a civil space program are summarized, noting that it is necessary to expand research concerning the Earth, the near-Earth environment, the Sun, the solar system, and the distant universe, to enhance the competitiveness of U.S. industry in launch vehicles and space applications, and to extend human presence beyond a permanently occupied space station to the Moon and Mars. It is recommended that support of the civil space program should be increased to about 1.3 percent of the overall federal budget. The main concerns of pursuing a civil space program include the development of the space technology base, the completion of current programs in science and infrastructure development, and avoiding cutbacks in research, technology, and development spending. R.B.

A89-13418
COST MODELLING FOR SPACE PROGRAMMES - THE COLUMBUS POLAR PLATFORM

H. C. LEESON (Logica Space and Defence Systems, Ltd., London, England) British Interplanetary Society, Journal (ISSN 0007-084X), vol. 41, Oct. 1988, p. 477-482.

As the cost of space projects continues to increase, a need has developed to examine proposed programs from a more critical economic stance. Late in 1987 the design and operational strategy of the polar platform element of the Columbus program was changed in response to a variety of technical, political and economic factors. One of a variety of sources of information which contributed to this change was a parametric life-cycle cost analysis carried out by a consortium of British companies, led by Logica of BNSC. This paper describes the stages through which the study progressed, from an initial definition of the baseline platform, through to a final analysis of the life-cycle cost trade-off between the different options under consideration. Author

A89-15294
PROPOSED PRINCIPLES ON THE USE OF NUCLEAR POWER SOURCES IN SPACE
GARY L. BENNETT (DOE, Office of Special Applications, Washington, DC) IN: 1988 IECEC; Proceedings of the Twenty-third Intersociety Energy Conversion Engineering Conference, Denver, CO, July 31-Aug. 5, 1988. Volume 3. New York, American Society of Mechanical Engineers, 1988, p. 23-27. refs

Recent United Nations regulatory activities with respect to space nuclear power systems are surveyed. The more general treaties and agreements applicable to space nuclear power are listed; the overall safety philosophy is discussed; the safety criteria proposed by the Working Group on the Use of Nuclear Power Sources in Outer Space in 1981 and 1988 are summarized; the implications of the Notification Convention of 1986 are considered; and particular attention is given to orbit prediction, search and recovery, and liability and insurance problems. T.K.

A89-16139
HUMAN ACTIVITIES IN OUTER SPACE - A FRAMEWORK FOR DECISION-MAKING
SIEGFRIED WIESSNER (Saint Thomas University, Miami, FL) IN: Space law: Views of the future. Deventer, Netherlands, Kluwer Law and Taxation Publishers, 1988, p. 7-20. refs

The 1967 Outer Space Treaty is discussed and a methodological framework is proposed for making decisions about space law. It is suggested that the framework is needed for dealing with issues which the treaty does not address. Problems addressed include sovereignty over celestial bodies, private enterprise in outer space, liability for damages caused by a space objects, and space debris. R.B.

A89-16520#
ADVANCED LAUNCH SYSTEM (ALS) PROGRAM STATUS AND PLANS
JACK WORMINGTON (USAF, Space Div., Los Angeles, CA) and A. DWIGHT ABBOTT (Aerospace Corp., Los Angeles, CA) AIAA, Space Programs and Technologies Conference, Houston, TX, June 21-24, 1988. 6 p. refs
(AIAA PAPER 88-3491)

The need for an Advanced Launch System Program to develop a new generation of space launch systems that would challenge present approaches, procedures, standards, and operations while fully utilizing available and emerging technologies is discussed. Program characteristics are discussed with attention given to mission requirements and system operability. In a discussion of baseline system concepts, consideration is given to vehicle concepts and operational concepts. K.K.

A89-17274
SPACE TRAVEL FOR EARTH - PRESENT AND FUTURE SOVIET SPACE TRAVEL [RAUMFAHRT FUER DIE ERDE - GEGENWART UND ZUKUNFT DER SOWJETISCHEN RAUMFAHRT]
UWE SCHMALING Astronautik (ISSN 0004-6221), vol. 25, July-Sept. 1988, p. 87-89. In German.

The goals of present and future Soviet space missions are examined. Long-term flights of the eighties and plans for the nineties are described, including plans for industrial production in space. Plans to go to Mars by the year 2000 are examined. The potential for Soviet efforts at an SDI-type program is considered. C.D.

A89-17653*# NASA Space Station Program Office, Reston, VA.
SPACE STATION FREEDOM - TECHNICAL AND MANAGEMENT CHALLENGES
THOMAS L. MOSER (NASA, Space Station Freedom Program Office, Reston, VA) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p. refs
(IAF PAPER 88-053)

The development of the Space Station is reviewed, focusing on the technical and managerial aspects of the program. The optimization of the Space Station configuration, utilization impacts on design, technical aspects of the distribution systems, and the problems of designing for a lifetime of 30 years or more are discussed. In addition, cost reduction studies, testing and verification, determining the assembly sequence, and operational communications and support systems are examined. Managerial aspects of the program include organization, program control, management tools and processes, and the integration of elements from the international partners. R.B.

A89-17831*# National Aeronautics and Space Administration, Washington, DC.
SPACE STATION FREEDOM - A RESOURCE FOR AEROSPACE EDUCATION
ROBERT W. BROWN (NASA, Educational Affairs Div., Washington, DC) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p. refs
(IAF PAPER 88-467)

The role of the International Space Station in future U.S. aerospace education efforts is discussed from a NASA perspective. The overall design concept and scientific and technological goals of the Space Station are reviewed, and particular attention is given to education projects such as the Davis Planetarium Student Space Station, the Starship McCullough, the Space Habitat, the working Space Station model in Austin, TX, the Challenger Center for Space Life Education, Space M+A+X, and the Space Science Student Involvement Program. Also examined are learning-theory aspects of aerospace education: child vs adult learners, educational objectives, teaching methods, and instructional materials. T.K.

A89-17858#
SPACE SYSTEMS AND THEIR RUNNING COSTS
J. MAJUS, P. KLEBER, R. SCHMID (DFVLR, Cologne, Federal Republic of Germany), and G. P. SEIDEL (MST, Munich, Federal Republic of Germany) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 13 p.
(Contract BMFT-01-QV-8798)
(IAF PAPER 88-571)

The follow-on (running) costs of a variety of space systems are studied and an approach for determining cost elements is developed. The defined cost breakdown structure is used to calculate corresponding cost figures for space systems including satellites, the Space Station, and the Space Shuttle. The figures are compared to the follow-on costs of a commerical airline, an experimental airplane, and a steel plant. It is found that the follow-on cost ratios for the airline and the industrial plant are about one order of magnitude higher than those of the space systems. It is suggested that the follow-on costs for space systems are typical for research projects. R.B.

A89-17864
MAJOR DEVELOPMENT TRENDS OF ORBITAL SPACE STATIONS
K. P. FEOKTISTOV (Academy of Sciences, Soviet National Association of Natural Sciences and Technology Historians, USSR) IAF, International Astronautical Congress, 39th, Bangalore, India, Oct. 8-15, 1988. 10 p.
(IAF PAPER 88-595)

C-3

The development history of orbiting space stations is reviewed, and the possible future of space stations is outlined. The Salyut and Mir stations are discussed. Basic trends in space station development are defined, including the creation of multipurpose orbital laboratories, the establishment of bases for servicing space vehicles in orbit, setting up a construction site for assembling major radiotelescopes, and organizing the production of superpure materials and medicinal and biological preparations. R.B.

A89-18310*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
THE ORGANIZED SPACE STATION
LEONG W. LEW (NASA, Johnson Space Center, Houston, TX) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 5 p. refs
(AIAA PAPER 88-4733)

Space Station organization designers should consider the onboard stowage system to be an integral part of the environment structured for productive working conditions. In order to achieve this, it is essential to use an efficient inventory control system able to track approximately 50,000 items over a 90-day period, while maintaining peak crew performance. It is noted that a state-of-the-art bar-code inventory management system cannot satisfy all Space Station requirements, such as the location of a critical missing item. O.C.

A89-18318*# Grumman Aerospace Corp., Bethpage, NY.
WORKSHOP IN THE SKY
LOUIS LEVOY, DONALD F. REIS (Grumman Corp., Grumman Aircraft Systems Div., Bethpage, NY), and ALBERTA QUINN (NASA, Marshall Space Flight Center, Huntsville, AL) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 8 p.
(AIAA PAPER 88-4742)

An evaluation of the historical experience of Apollo, Skylab, and the Space Shuttle shows it to be both feasible and prudent to furnish a minimal capability for Space Station maintenance. The ability to perform orbital replacement unit-related maintenance, as well as opportune in-orbit repair, is believed to be essential for crew and Station survival, mission effectiveness, and maximum productivity. Attention is given to problems associated with mechanical repair, welding, and composite bonding, as well as to recommended tools and procedures. O.C.

A89-18319*# Grand Valley State Coll., Allendale, MI.
EVALUATION OF THE BENEFITS AND FEASIBILITY OF ON-ORBIT REPAIR BY COMPARISON WITH OPERATIONS IN AN ANALOGOUS ENVIRONMENT - HOW IS THE FREEDOM SPACE STATION LIKE AN OCEANOGRAPHIC EXPEDITION?
WILLIAM C. LEWIS (Grand Valley State University, Allendale; Research and Technology Institute, Grand Rapids, MI) IN: AIAA/SOLE Space Logistics Symposium, 2nd, Costa Mesa, CA, Oct. 3-5, 1988, Proceedings. Washington, DC, American Institute of Aeronautics and Astronautics, 1988, 8 p. NASA-supported research.
(AIAA PAPER 88-4743)

Equipment maintenance and logistics strategies followed on the R/S Thompson, an oceanographic research vessel, are described, and parallels are drawn between the problems and solutions of an oceanographic expedition and those of a space station mission. Presumably oceanic expeditions, which have been conducted for over 150 years, have developed effective methods of equipment maintenance. Similarities are found in relative budget and equipment maintenance problems, but few similarities are found in solutions to these problems. It is speculated that the high relative cost of on-orbit work is responsible, and that development of significantly more effective component level fault diagnosis equipment and repair equipment could enable application of oceanographic equipment maintenance strategies, enhancing safety and speeding laboratory work while giving significant cost reduction. Author

A89-18950
PROPOSED REVISIONS TO AMERICA'S NATIONAL AIRSPACE SYSTEM - A CRISIS IN LEADERSHIP?
ALAN ARMSTRONG Air Law (ISSN 0165-2079), vol. 13, Oct. 1988, p. 172-177. refs

The paper discusses the legislative origins of a debate concerning the extent to which Mode 'C' (altitude reporting) transponder equipment may be required of aircraft operated in U.S. airspace. The current proposal regarding Mode 'C' equipment and airspace reconfiguration advanced by the FAA is examined as well as Congressional and general aviation's response to the proposal. An attempt is made to find alternate solutions to the problems which caused the debate in the first place. K.K.

A89-19384
THE NASA PROGRAMME IN THE 1990S AND BEYOND
Space Policy (ISSN 0265-9646), vol. 4, Nov. 1988, p. 273-280.

Economic aspects of NASA program planning are discussed, summarizing a report published by the Congressional Budget Office in May 1988. The presently proposed core program (with the Space Station as the main project and the Space Shuttle as the main STS) is shown to represent a middle path between expansive planning with significantly increased budgets (including a lunar base or manned mission to Mars by around the year 2000) and zero budget growth (forcing delay of the Space Station and more unmanned missions). Core-program funding would increase gradually, from $9 billion in 1988 to $14.4 billion (1988 dollars) in 1993 and $16.4 billion in 2000. The breakdown of expenditures in these three plans is explored in detail; the implications for U.S. space leadership are examined; and the effects of increased space commercialization are considered. T.K.

A89-19388
THE DECISION TO BUILD THE SPACE STATION - TOO WEAK A COMMITMENT?
HOWARD E. MCCURDY (American University, Washington, DC) Space Policy (ISSN 0265-9646), vol. 4, Nov. 1988, p. 297-306. refs

The history of NASA's efforts to gain Presidential and Congressional approval for the International Space Station (ISS) is examined critically, with a focus on the impact of incremental decision-making (IDM) and the reluctance of government to fund programs on a long-term basis. Topics addressed include early objections to the ISS on scientific, technological, and economic grounds; the dominant role of IDM in defining both the Space Shuttle and ISS programs; the initial emphasis on ISS missions and utilization rather than specific configurations; and the mutually incompatible performance requirements that sometimes resulted. Consideration is given to the distributed ISS architecture, military use of the ISS, and the problem of conflicting cost estimates. It is argued that the IDM involved in every step of the approval process will leave the ISS permanently vulnerable to redefinition and cutbacks, seriously affecting program stability. T.K.

A89-19389
US SPACE TRANSPORTATION POLICY - HISTORY AND ISSUES FOR A NEW ADMINISTRATION
SCOTT PACE Space Policy (ISSN 0265-9646), vol. 4, Nov. 1988, p. 307-318. refs

The space policy decisions facing the incoming U.S. administration are examined on the basis of a historical review of NASA programs and the governmental decision-making processes which defined them. Topics discussed include the Space Shuttle program, the transition from ELVs to the Space Shuttle, the loss of the Challenger and its impact, and current military and NASA programs and funding levels. Particular attention is given to the roles of NASA, Congress, DOD, and administration in the Advanced Launch System program. The major issues identified for 1989 are (1) deployment or nondeployment of SDI, (2) commitment to a civilian manned presence in space, and (3) support for an internationally competitive space industry. T.K.

A89-19390
LAW ABOARD THE SPACE STATION
SCOTT F. MARCH Space Policy (ISSN 0265-9646), vol. 4, Nov. 1988, p. 328-335. refs

Problems of legal jurisdiction over the activities of individual Space Station crew members are discussed. Consideration is given to international treaties and regulations; U.S. federal legislation; the proliferation of U.S. state law into outer space; the Space Station Intergovernmental Agreements signed by the U.S., Canada, ESA, and Japan; and previously proposed alternative solutions to the jurisdiction question. It is concluded that the regulations and agreements currently in force are insufficient and in many cases ambiguous. T.K.

A89-19850
INTRODUCTION TO SPACE: THE SCIENCE OF SPACEFLIGHT
THOMAS D. DAMON (Pikes Peak Community College, CO) Malabar, FL, Orbit Book Co., 1989, 238 p. refs

The history, current status, and future potential of astronautics are examined, with a focus on technological aspects, in an introduction for general readers. Chapters are devoted to the early Soviet and NASA space missions, propulsion systems, orbits, the space environment, satellites, remote sensing, space defense, the Space Shuttle, living in space, working in space, space stations, planetary colonization, and SETI. Extensive drawings, diagrams, photographs, and a glossary are provided. T.K.

A89-20846* Fairchild Space and Electronics Co., Germantown, MD.
CETF SPACE STATION PAYLOAD POINTING SYSTEM DESIGN AND ANALYSIS FEASIBILITY STUDY
TOM SMAGALA (Fairchild Space Sherman Technology Center, Germantown, MD) and DAVE MCGLEW (NASA, Goddard Space Flight Center, Greenbelt, MD) IN: Guidance and control 1988; Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Jan. 30-Feb. 3, 1988. San Diego, CA, Univelt, Inc., 1988, p. 293-313. refs
(AAS PAPER 88-041)

The expected pointing performance of an attached payload coupled to the Critical Evaluation Task Force Space Station via a payload pointing system (PPS) is determined. The PPS is a 3-axis gimbal which provides the capability for maintaining inertial pointing of a payload in the presence of disturbances associated with the Space Station environment. A system where the axes of rotation were offset from the payload center of mass (CM) by 10 in. in the Z axis was studied as well as a system having the payload CM offset by only 1 inch. There is a significant improvement in pointing performance when going from the 10 in. to the 1 in. gimbal offset. K.K.

A89-21398
SPACE-GROWN PROTEIN CRYSTALS WILL AID IN DRUG RESEARCH
Aviation Week and Space Technology (ISSN 0005-2175), vol. 129, Dec. 19, 1988, p. 56, 57.

The use of microgravity to grow protein crystals in space for pharmaceutical research is examined. Several companies and researchers involved in the Space Shuttle Mission 26 experiment are noted and the crystals grown on the mission are described. Crystal growth on the Mir space station and a crystal growth system launched by the Long March 1 are considered. Plans for crystal growth on the Space Station Mission 29 are discussed. R.B.

A89-21402
U.S. SPACE POLICY. II [LA POLITIQUE SPATIALE AMERICAINE. II]
LOUIS LAIDET L'Aeronautique et l'Astronautique (ISSN 0001-9275), no. 132, 1988, p. 16-22. In French.

Changes in U.S. civil space policy are pointed out, with special attention given to recent improvements in relations between the U.S. and other countries. The 1987 space cooperation agreement between the U.S. and the USSR has resulted in the planning of such joint programs as the Global Change project and manned and unmanned missions to Mars. Other recent indications of the cooperative posture of the U.S. include the Pollack study of potential foreign competition and cooperation and plans for an 'international space year' in 1992. R.R.

A89-21796#
AEROSPACE '88
LARRY A. DIEHL, DELMA C. FREEMAN, MARK HENLEY, NANCY GIDDINGS, LUKE FRANSCINI, III et al. Aerospace America (ISSN 0740-722X), vol. 26, Dec. 1988, p. 12-16, 18-22, 24-26 (45 ff.).

The year 1988's most significant events in the various fields of the aerospace industry in the U.S. are discussed. Attention is given to aeroacoustics, aerodynamic decelerators, aerospace maintenance, aerospace power, airbreathing propulsion, air transportation, aircraft design, aircraft operations, astrodynamics, flight mechanics, C3I, CAD/CAM, digital avionics, economics, electric propulsion, flight simulation, general aviation, interactive computer graphics, LTA, liquid rocket propulsion, materials, missiles, lasers, propellants, sensors, software, space operations and support, space transportation, structural dynamics, support systems, thermophysics, and V/STOL. O.C.

A89-23252
THE ESSENTIAL STEP
FRANK COLUCCI Space (ISSN 0267-954X), vol. 4, Mar.-Apr. 1988, p. 10-15.

The detailed design and development phase, Phase C/D, of the Space Station program is discussed. The programs of the four work packages involved with Phase C/D are examined. The development of the pressurized modules and research nodes, environmental control systems, propulsion systems, space transfer vehicles, structural framework, habitat module, data management system, the free-flying platforms, power systems, and guidance, navigation, and control systems are reviewed. R.B.

A89-23254
SHUTTLE C LOADS UP
FRANK COLUCCI Space (ISSN 0267-954X), vol. 4, Mar.-Apr. 1988, p. 20, 21, 23.

The development of the Shuttle C, an unmanned heavy lift launch vehicle derived from the Space Shuttle, is examined. Proposed missions for the Shuttle C are considered, including the Space Station and testing of the Advanced Solid Rocket Motor for the Space Shuttle. Also, options for the design, construction, propulsion, and avionics of the Shuttle C are discussed. R.B.

A89-23851
SOVIETS IN SPACE
PETER M. BANKS and SALLY K. RIDE (Stanford University, CA) Scientific American (ISSN 0036-8733), vol. 260, Feb. 1988, p. 32-40. refs

The Soviet space program is discussed, focusing on satellite, space station, and space shuttle programs. The history of Soviet activities in space is reviewed. Soviet launch vehicles and spacecraft are illustrated, including the Soviet space shuttle and the Proton and Energiya launch vehicles. The programs of the Salyut and Mir space stations are examined, including the experiments aboard the Kvant module. R.B.

A89-26376
COMMERCIAL OPPORTUNITIES IN SPACE; SYMPOSIUM, TAIPEI, REPUBLIC OF CHINA, APR. 19-24, 1987, TECHNICAL PAPERS
F. SHAHROKHI, ED., K. E. HARWELL, ED. (Tennessee, University, Tullahoma), and CHI-CHANG CHAO, ED. (National Cheng Kung University, Tainan, Republic of China) Symposium sponsored by the University of Tennessee, National Cheng Kung University, AIAA, et al. Washington, DC, American Institute of Aeronautics and Astronautics, Inc. (Progress in Astronautics and Aeronautics. Volume 110), 1988, 557 p. For individual items see A89-26377 to A89-26405.

Papers concerning commercial opportunities in space are presented, including topics such as space transportation, the U.S. Laboratory Module, the Ariane 5 Extended Stage, planning Columbus operations, the use of computers in designing and cost modeling space transportation systems, manned on-orbit assembly, construction of the Space Station, space processing of metals and alloys, materials processing using free-flying platforms, bioprocessing in space, electronic and containerless materials processing, and measuring the Soret effect in microgravity. Topics related to satellite communications and remote sensing include the development of communication satellite technology, the design of a multibeam maritime mobile satellite system with reusable frequencies, the Distress Radio Call System, galactic communication with small duty cycles, a wideband communications satellite for Europe, communication satellite technnology in Japan, a transportable tracking and receiving station for polar orbiting remote sensing satellites, the use of Landsat MSS and TM data for geological resource exploration, plans for Landsat 6 and 7, mapping from satellites, the Janus Earth Observation Satellite, MOMS, and mapping with SPOT data. Other aspects include propulsion for the Space Station, radiation associated with the Space Shuttle Reaction Control System, a lightweight electrostatic generator, lunar-based energy and power systems, concrete for lunar base construction, and the physical properties of concrete made with a lunar soil sample. R.B.

A89-26390#
KINETIC OF THE SORET EFFECT AND ITS MEASUREMENT UNDER MICROGRAVITY CONDITIONS
S. R. VAN VAERENBERGH and J. C. LEGROS (Bruxelles, Universite Libre, Brussels, Belgium) IN: Commercial opportunities in space; Symposium, Taipei, Republic of China, Apr. 19-24, 1987, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, Inc., 1988, p. 222-239. Research supported by La Loterie Nationale, SPPS, and FRFC. refs

Plans to measure the Soret coefficient on twenty different systems under microgravity conditions during the automatic platform Eureca 1 mission are discussed. A description of the hardware is given. The kinetic of the Soret separation is described, showing that the variation of the concentration is much faster near the solid boundaries than in the bulk of the liquid phase. The Soret separation influence on the hydrodynamic stability of liquid system is analyzed. Author

A89-27788
DEFINITION AND DESIGN OF AN OPERATIONAL ENVIRONMENT-MONITORING SYSTEM
J. C. VENEMA and H. A. VAN INGEN SCHENAU (Nationaal Lucht-en Ruimtevaartlaboratorium, Amsterdam, Netherlands) IN: Recent advances in sensors, radiometry, and data processing for remote sensing; Proceedings of the Meeting, Orlando, FL, Apr. 6-8, 1988. Bellingham, WA, Society of Photo-Optical Instrumentation Engineers, 1988, p. 328-331. Research supported by UN and Ministry of Foreign Affairs of the Netherlands. refs

The definition and design of an operational environment-monitoring system are described. The system supports the principal information demands of the Food and Agriculture Organization of the United Nations by monitoring ecological conditions in Africa. Author

A89-28450#
A NATIONAL PROGRAM FOR THE SCIENTIFIC AND COMMERCIAL USE OF SHUTTLE EXTERNAL FUEL TANKS IN SPACE
RANDOLPH H. WARE (University Corporation for Atmospheric Research; External Tanks Corp., Boulder, CO) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 17 p.
(AIAA PAPER 89-0728)

The possibilities of applying the expended Space Shuttle external fuel tanks to practical uses in space are addressed. The external tanks are described and the history of the use of expended fuel tanks in space is reviewed. Suborbital use of the tanks as experimental sites is examined. The suitability of such a site for thermosphere density measurements, chemical release experiments, hydrogen release, microgravity experiments, epitaxy experiments, space debris detection, remote sensing, tether experiments, and attitude and orbit control is examined. The orbital use of the tanks for synthetic aperture radar and as tended, pressurized platforms is considered, and the storage of the external tanks in orbit is addressed. C.D.

A89-29150
ECONOMICS AND TECHNOLOGY IN U.S. SPACE POLICY
MOLLY K. MACAULEY, ED. (Resources for the Future, Inc., Washington, DC) Washington, DC, Resources for the Future, Inc., 1987, 282 p. No individual items are abstracted in this volume.

Various papers on economics and technology in U.S. space policy are presented. Individual topics addressed include: the contribution of a partnership between economics and technology; technology, economics, and international cooperation in earth observations; perspectives on materials processing in space; space transportation; challenges ahead for the communications satellite industry; a manufacturer's view of commercial activity in space; insurance, risk sharing, and incentives for commercial use of space. Also considered are: the government's role in the commercialization of new technology; the economics of the Space Station; changes and challenges in the global context; commercial policies and international competition in space transportation policy; natural monopoly in commercial satellite systems; and the need for rational analysis in the U.S. space program. C.D.

A89-31554
A SUSTAINABLE RATIONALE FOR MANNED SPACE FLIGHT
JOHN M. LOGSDON (George Washington University, Washington, DC) Space Policy (ISSN 0265-9646), vol. 5, Feb. 1989, p. 3-6.

Reasons for maintaining a manned space program are discussed. An historical overview of the basis of the manned space program is presented. It is suggested that political and public support for an unmanned program would be small, leading to a reduction in the space program budget. The development of the Space Station and the possibility of using the Station in the establishment of bases on the moon or Mars are examined. R.B.

A89-31556
TOWARDS A BAN ON NUCLEAR POWER IN EARTH ORBIT
STEVEN AFTERGOOD (Committee to Bridge the Gap, Los Angeles, CA) Space Policy (ISSN 0265-9646), vol. 5, Feb. 1989, p. 25-40. refs

The risks and benefits of space nuclear power are evaluated. Arguments supporting the proposed ban on nuclear power in earth orbit by von Hippel and Sagdeev (1988) are presented. The conceptual design of a space nuclear power system, the history of space nuclear power, and current U.S. programs are reviewed. Soviet and American nuclear-powered spacecraft and accidents and failures involving these spacecraft are listed. The applications of space nuclear power supply systems are examined, emphasizing the use of these systems for SDI. R.B.

A89-31610* Lockheed Engineering and Sciences Co., Houston, TX.
PREVIOUS EXPERIENCE IN MANNED SPACE FLIGHT - A SURVEY OF HUMAN FACTORS LESSONS LEARNED
GEORGE O. CHANDLEE (Lockheed Engineering and Sciences Co., Houston, TX) and BARBARA WOOLFORD (NASA, Johnson Space Center, Houston, TX) IN: Human Factors Society, Annual Meeting, 32nd, Anaheim, CA, Oct. 24-28, 1988, Proceedings. Volume 1. Santa Monica, CA, Human Factors Society, 1988, p. 49-52. refs
(Contract NAS9-17900)

Human factors data from Apollo, Skylab, and Space Shuttle flights are reviewed. The sources of data and collection methods are described. A classification scheme for human factors data is proposed. The implications of the results for the design of the Space Station program are considered. R.B.

N89-10071*# Computer Sciences Corp., Beltsville, MD. System Sciences Div.
SPACE STATION PLATFORM MANAGEMENT SYSTEM (PMS) REPLANNING USING RESOURCE ENVELOPES
JOY LEE BUSH, ANNA CRITCHFIELD, and AUDREY LOOMIS *In* NASA, Goddard Space Flight Center, Proceedings of 1987 Goddard Conference on Space Applications of Artificial Intelligence (AI) and Robotics 17 p 1987
Avail: NTIS HC A99/MF E03 CSCL 05A

One of the responsibilities of the Space Station Platform Management System (PMS) is to maintain constraint-free, short-term plans for platform and free-flyer activities. Both the replanning function and the associated constraint-checking function are viewed as potentially requiring expert system assistance. The PMS Resource Envelope Scheduling System (PRESS) expert system, which is currently under development, is described. The PRESS capabilities will include the following: plan, replan, and perform constraint checking using resource envelopes resembling those required for telescience; initialize itself using the results fo a previous run; infer the replanning needs associated with a change in resource availability; allow the user to determine the level of interaction (including an advisory capability) with the system during execution; and generate both a graphic timeline and a report as output. The PRESS is being developed on an IBM PC/AT using TeKnowledge, Inc.'s M.1 expert system shell. The PRESS activity definitions and constraints are based on those defined for the Cosmic Background Explorer (COBE) mission scheduled for launch in early 1989. Author

N89-10677# Commerce Dept., Washington, DC.
SPACE COMMERCE: AN INDUSTRY ASSESSMENT
May 1988 138 p
(PB88-214069) Avail: NTIS HC A07/MF A01 CSCL 05A

Existing and potential worldwide markets are identified for space related goods and services, focusing on five major areas: (1) Space Transportation; (2) Satellite Communications; (3) Satellite Remote Sensing; (4) Space Based Industrial Facilities; and (5) Materials Research and Processing in Space. Aspects of Insurance and Finance relevant to commercial ventures in these markets are examined. Finally, assessments are presented from U.S. industry representatives on their ability to compete against foreign competition in each of the five major areas. GRA

N89-11760*# National Aeronautics and Space Administration, Washington, DC.
TECHNOLOGY FOR FUTURE NASA MISSIONS: CIVIL SPACE TECHNOLOGY INITIATIVE (CSTI) AND PATHFINDER
Sep. 1988 550 p Conference held in Washington, D.C., 12-13 Sep. 1988; sponsored in part by NASA and AIAA
(NASA-CP-3016; NAS 1.55:3016) Avail: NTIS HC A23/MF A01 CSCL 22/1

Information is presented in viewgraph form on a number of related topics. Information is given on orbit transfer vehicles, spacecraft instruments, spaceborne experiments, university/industry programs, spacecraft propulsion, life support systems, cryogenics, spacecraft power supplies, human factors engineering, spacecraft construction materials, aeroassist, aerobraking and aerothermodynamics.

N89-11775*# National Aeronautics and Space Administration, Washington, DC.
HUMANS IN SPACE
JAMES P. JENKINS *In its* Technology for Future NASA Missions: Civil Space Technology Initiative (CSTI) and Pathfinder p 305-314 Sep. 1988
Avail: NTIS HC A23/MF A01 CSCL 22/1

Information is given in viewgraph form on humans in space. Information is given on extravehicular activity/space suit project objectives and program schedule, and space human factors objectives and products. R.J.F.

N89-12106# Instituto de Pesquisas Espaciais, Sao Jose dos Campos (Brazil).
AN AGRICULTURAL CROP YIELD MODEL BY SATELLITE: A SIMULATION [UMMODELO DE PRODUTIVIDADE AGRICOLA POR SATELITE: UMA SIMULACAO]
FAUSTO CARLOSDEALMEIDA, CORINA DACOSTAFREITASYANASSE, and THELMA KRUG Aug. 1988 25 p In PORTUGUESE; ENGLISH summary Presented at the 2nd Latin American Symposium of Remote Sensing, Bogota, Columbia, 16-20 November 1987
(INPE-4639-PRE/1350) Avail: NTIS HC A03/MF A01

Variables derived from rainfall and sunshine are used in a crop yield model called the Method of Critical Periods proposed by Celaschi and Almeida and developed by Celaschi, aiming at the estimation of crop yields using satellite data. These variables, which can be extracted from environmental satellites, are simulated from conventional meteorological data gathered at the surface. The variables derived from rainfall are of the dummy type associated with the incidence of rainfall beyond a threshhold value, while the variable derived from sunshine hours is weighted by calk of rainfall, expressing the tendency for water stress. The model was tested for corn in the State of Sao Paulo, Brazil. The results are compared with those obtained by the conventional method employing temperature and rainfall and with the officially reported data for the state of Sao Paulo. Author

N89-12575# Martin Marietta Corp., New Orleans, LA.
A TEACHER'S COMPANION TO THE SPACE STATION: A MULTI-DISCIPLINARY RESOURCE
LYNN P. HAGAN and LIZ ELSEN 1988 67 p Prepared in cooperation with Louisiana Nature and Science Center, New Orleans
Avail: NTIS HC A04/MF A01

The United States Space Station promises to be an adventure in enterprise and ingenuity. This collection of activities, geared for students from kindergarten through high school, promises to help them become aware of the potential of space. Within their lifetime, men and women will be living in space on a routine basis, carrying out activities once only dreamt of in books. Author

N89-14172*# National Aeronautics and Space Administration, Washington, DC.
THE 1989 LONG-RANGE PROGRAM PLAN
19 Dec. 1988 229 p
Avail: NTIS HC A11/MF A01 CSCL 05/1

The President's National Space Policy of 1988 reaffirms that space activities serve a variety of vital national goals and objectives, including the strengthening of U.S. scientific, technological, political, economic, and international leadership. The new policy stresses that civil space activities contribute significantly to enhancing America's world leadership. Goals and objectives must be defined and redefined, and each advance toward a given objective must be viewed as a potential building block for future programs. This important evolutionary process for research and development is reflected, describing NASA's program planning for FY89 and later years. This plan outlines the direction of NASA's future activities by discussing goals, objectives, current programs, and plans for the future. The 1989 plan is consistent with national policy for both space and aeronautics, and with the FY89 budget that the President submitted to Congress in February 1988. Author

N89-14180# Committee on Commerce, Science, and Transportation (U.S. Senate).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION, PART 3
1988 148 p Hearing before the Subcommittee on Science, Technology and Space of the Committee on Commerce, Science and Transportation, 100th Congress, 2d Session, 22 Mar. 1988
(S-HRG-100-579-PT-3; GPO-87-269) Avail: Subcommittee on Science, Technology and Space of the Committee on Commerce, Science and Transportation, Senate, Washington, D.C. 20510 HC free; SOD SN-552-070-045-89-9 HC $4.25

Funding for the restoration of the space shuttle to safe flight; the National Space Policy; and the NASA budget are discussed. B.G.

N89-14181# Committee on Science, Space and Technology (U.S. House).
THE 1989 NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AUTHORIZATION, VOLUME 2
1988 1133 p Hearings before the Subcommittee on Space Science and Applications of the Committee on Science, Space and Technology, 100th Congress, 2d Session, 3; 8-10; 22-24; 29-31 Mar. 1988
(GPO-86-904) Avail: Subcommittee on Space Science and Applications of the Committee on Science, Space and Technology, House of Representatives, Washington, D.C. 20515 HC free; SOD SN-552-070-050-23-0 HC $29.00

Funding for the restoration of the space shuttles to eliminate payload backlog; restoration of the U.S. leadership in space; the space station; and continuity and advances in space science, aeronautics and space technology is discussed. B.G.

N89-14684*# National Aeronautics and Space Administration, Washington, DC.
LIVING IN SPACE
SHEILA BRISKIN ANDREWS and AUDREY KIRSCHENBAUM 1988 63 p Original doc. contains color illustrations
(NASA-EP-222; NAS 1.19:222) Avail: SOD HC $4.75 as 033-000-01000-1 CSCL 06/11

Operation Liftoff was designed to encourage pupils in the nation's elementary schools to take a greater interest in mathematics and science. Topics addressed include: food, clothing, health, housing, communication, and working. Each unit consists of background information, a teacher printout (lesson plan), and student liftoff (activities) for levels A, B, and C. B.G.

N89-14998*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
EXPERIMENTS IN PLANETARY AND RELATED SCIENCES AND THE SPACE STATION
RONALD GREELEY, ed. (Arizona State Univ., Tempe.) and RICHARD J. WILLIAMS, ed. Washington, DC Nov. 1987 188 p Workshop held in Tempe, AZ, 15-16 Sep. 1986
(Contract NCC9-14; NAS9-17023)
(NASA-CP-2494; S-566; NAS 1.55:2494) Avail: NTIS HC A09/MF A01 CSCL 03/2

Numerous workshops were held to provide a forum for discussing the full range of possible experiments, their science rationale, and the requirements on the Space Station, should such experiments eventually be flown. During the workshops, subgroups met to discuss areas of common interest. Summaries of each group and abstracts of contributed papers as they developed from a workshop on September 15 to 16, 1986, are included. Topics addressed include: planetary impact experimentation; physics of windblown particles; particle formation and interaction; experimental cosmochemistry in the space station; and an overview of the program to place advanced automation and robotics on the space station.

N89-15003*# National Aeronautics and Space Administration, Washington, DC.
REPORT ON OTHER PROPOSALS FOR SSPEX
JOSEPH A. NUTH, GEORGE J. CORSO, DONALD DEVINCENZI, AL DUBA, JOHN W. FREEMAN, RAMON LOPEZ, JAMES STEPHENS, IAN STRONG, and JOHN WOLFE (San Jose State Univ., Calif.) *In* NASA, Lyndon B. Johnson Space Center, Experiments in Planetary and Related Sciences and the Space Station 5 p Nov. 1987
Avail: NTIS HC A09/MF A01 CSCL 03/2

The only unifying factor among the experiments discussed is that they are all unique Opportunities and/or Techniques for High-caliber Experimental Research (OTHER). Thirteen of the experiments are briefly described. B.G.

N89-15286*# Eagle Engineering, Inc., Houston, TX.
LUNAR BASE SCENARIO COST ESTIMATES: LUNAR BASE SYSTEMS STUDY TASK 6.1
31 Oct. 1988 294 p
(Contract NAS9-17878)
(NASA-CR-172103; NAS 1.26:172103; EEI-88-211) Avail: NTIS HC A13/MF A01 CSCL 13/2

The projected development and production costs of each of the Lunar Base's systems are described and unit costs are estimated for transporting the systems to the lunar surface and for setting up the system. Author

N89-15790*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SPACE STATION INDUCED MONITORING
JAMES F. SPANN, ed. and MARSHA R. TORR, ed. Washington, DC Nov. 1988 85 p Conference held in Huntsville, AL, 10-11 May 1988 Sponsored by NASA, Washington
(NASA-CP-3021; M-602; NAS 1.55:3021) Avail: NTIS HC A05/MF A01 CSCL 22/2

This report contains the results of a conference convened May 10-11, 1988, to review plans for monitoring the Space Station induced environment, to recommend primary components of an induced environment monitoring package, and to make recommendations pertaining to suggested modifications of the Space Station External Contamination Control Requirements Document JSC 30426. The contents of this report are divided as Follows: Monitoring Induced Environment - Space Station Work Packages Requirements, Neutral Environment, Photon Emission Environment, Particulate Environment, Surface Deposition/Contamination; and Contamination Control Requirements.

N89-15791*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
SUMMARY OF REQUIREMENTS IN NASA WORK PACKAGE NO. 2
L. LEGER and H. EHLERS *In* NASA, Marshall Space Flight Center, Space Station Induced Monitoring p 1-4 Nov. 1988
Avail: NTIS HC A05/MF A01 CSCL 22/2

Work package No. 2 (WP2) has a section in the proposal dealing with measurements of the environment. The quantities to be measured as well as the instruments to be used are summerized. The information provided is only a cursory overview of what has been considered at the time of the proposal. Nevertheless the general ideas are given that much work needs to be done to develop specifics. It is important to note that measurements in the field of particles and waves are not part of the proposal. On the other hand, some of the environmental measurements planned and included in the proposal do not fall within the category of contamination. Some concepts of environment monitoring configurations are also given. Author

N89-17614# Committee on Science, Space and Technology (U.S. House).
ORBITAL SPACE DEBRIS
1988 111 p Hearing before the Subcommittee on Space Science Applications of the Committee on Science, Space and Technology, 100th Congress, 2d Session, No. 112, 13 Jul. 1988
(GPO-88-188) Avail: Subcommittee on Space Science and Applications of the Committee on Science, Space and Technology, House of Representative, Washington, D.C. 20515 HC free; SOD SN 552-070-048-69-3 HC $3.00

A Hearing before the Subcommittee of Space Science Applications of the Committee on Science, Space and Technology, of the House of Representatives (100th Congress, second session), on 13 July 1988, discussed the problem of orbital space debris. Some 7000 spent spacecraft rockets, spent upper stages, separation devices, fragments of exploded systems are abandoned in Earth orbit at a rough altitude of 800 miles, where they are being tracked by radar. They present a clear danger to future space flight. In addition, there is other orbital debris too small to be tracked by present day radar. Steps are being taken by NASA

and DOD to try to reduce the amount of space debris being created, and to improve the ability of radar to track the smaller bits and pieces. F.M.R.

N89-18261# Committee on Appropriations (U.S. Senate).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
In its Department of Housing and Urban Development and Certain Independent Agencies Appropriations for Fiscal Year 1989, Part 2 p 537-676 1988
Avail: Committee on Appropriations, Senate, Washington, DC 20515 HC free; SOD HC $19.00 as 552-070-05046-1

Hearings before a subcommittee of the Senate Committee on Appropriations are presented along with justifications for research and development, construction of facilities, space flight and communications, space station cost increases, and cost overruns. Equal opportunity employment, international cooperation, shuttle safety, and space station user community involvement were also discussed. B.G.

N89-18386*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE DREAM OF A NATION
ALFREDO MARTINEZ *In its* NASA Ames Summer High School Apprenticeship Research Program: 1986 Research Papers p 43-47 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 05/4

A challenging new era is under consideration and on its way. With it, comes new problems and questions to solve and answer. Nevertheless, positive thinking is required of all those who participate in or share part of the Space Station's responsibility. Hence, no longer is space an unknown, unreachable environment. It is simply a place for men and women to live, work, and learn. Author

N89-18389*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE SPACE STATION
ABRAHAM MUNOZ *In its* NASA Ames Summer High School Apprenticeship Research Program: 1986 Research Papers p 63-67 Sep. 1988
Avail: NTIS HC A07/MF A01 CSCL 22/2

Conceived since the beginning of time, living in space is no longer a dream but rather a very near reality. The concept of a Space Station is not a new one, but a redefined one. Many investigations on the kinds of experiments and work assignments the Space Station will need to accommodate have been completed, but NASA specialists are constantly talking with potential users of the Station to learn more about the work they, the users, want to do in space. Present configurations are examined along with possible new ones. Author

N89-18508# Air War Coll., Maxwell AFB, AL.
THE SPACE SHUTTLE VERSES EXPENDABLE LAUNCH VEHICLES LESSONS FOR THE FUTURE
ROBERT M. MIHARA Apr. 1988 33 p
(AD-A202014) Avail: NTIS HC A03/MF A01 CSCL 22/5

During the development of the space shuttle, the United States space launch strategy changed from a mix of Expandable Launch Vehicles (ELVs) and shuttles to depending exclusively of the shuttle. And, for awhile the strategy seemed to be working. Then, in January 1986, on the system's 25th launch, the space shuttle Challenger exploded during takeoff and the flaw in strategy was painfully obvious to everyone. Any significant problem with the shuttle could and would ground it until the problem was corrected. A process that could take years. In the meantime, the nation would be without a launch capability. The space community lost no time in returning to a mix of ELVs and shuttles strategy. Looking to the future, the National Aerospace Plane or the Heavy Lift Vehicle will give the nation another chance to debate what its national space launch strategy should be. This report explores the decision making process which led up to this shuttle only launch strategy to see if there are any lessons to be learned for this upcoming debate. GRA

N89-19324*# North Dakota Univ., Grand Forks. Dept. of Space Studies.
VARIABLE GRAVITY RESEARCH FACILITY
SEAN ALLAN, STAN ANCHETA, DONNA BEINE, BRIAN CINK, MARK EAGON, BRETT ECKSTEIN, DAN LUHMAN, DANIEL MCCOWAN, JAMES NATIONS, TODD NORDTVEDT et al. 13 Jun. 1988 96 p
(Contract NGT-21-002-080)
(NASA-CR-184714; NAS 1.26:184714) Avail: NTIS HC A05/MF A01 CSCL 14/2

Spin and despin requirements; sequence of activities required to assemble the Variable Gravity Research Facility (VGRF); power systems technology; life support; thermal control systems; emergencies; communication systems; space station applications; experimental activities; computer modeling and simulation of tether vibration; cost analysis; configuration of the crew compartments; and tether lengths and rotation speeds are discussed. B.G.

N89-20073*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)/AMERICAN SOCIETY FOR ENGINEERING EDUCATION (ASEE) SUMMER FACULTY FELLOWSHIP PROGRAM 1988, VOLUME 2
RICHARD B. BANNEROT and STANLEY H. GOLDSTEIN Feb. 1989 177 p Program held in Houston, TX, 1988 Sponsored by NASA, Washington
(Contract NGT-44-005-803)
(NASA-CR-172118-VOL-2; NAS 1.26:172118-VOL-2) Avail: NTIS HC A09/MF A01 CSCL 05/9

The 1988 Johnson Space Center (JSC) National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program was conducted by the University of Houston and JCS. The 10-week program was operated under the auspices of the ASEE. The program at JSC, as well as the programs at other NASA Centers, was funded by the Office of University Affairs, NASA Headquarters, Washington, D.C. The objectives of the program, which began in 1965 at JSC and in 1964 nationally, are: (1) to further the professional knowledge of qualified engineering and science faculty members; (2) to stimulate an exchange of ideas between participants and NASA; (3) to enrich and refresh the research and teaching activities of participants' institutions; and (4) to contribute to the research objectives of the NASA Centers.

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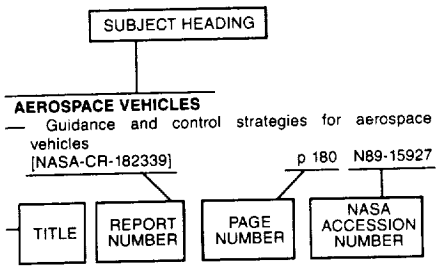

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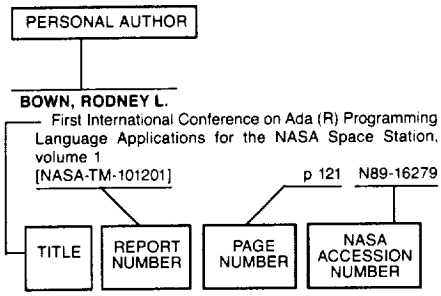

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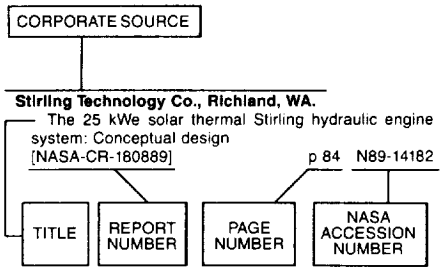

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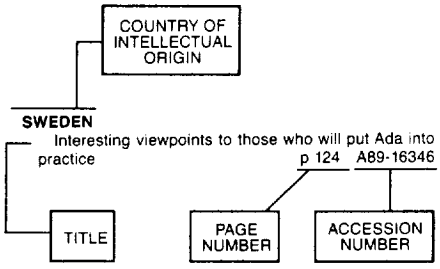

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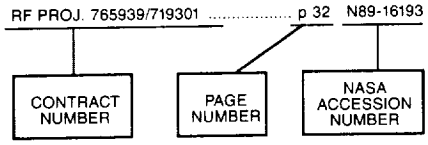

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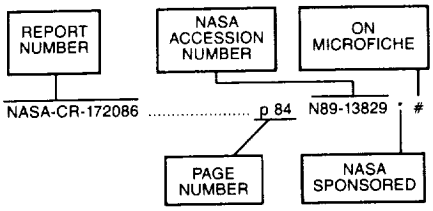

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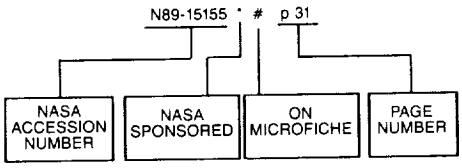

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1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA SP-7056 (09)		

4. Title and Subtitle	5. Report Date
Space Station Systems A Bibliography with Indexes	November 1989
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
	10. Work Unit No.
9. Performing Organization Name and Address National Aeronautics and Space Administration Washington, DC 20546	11. Contract or Grant No.
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	14. Sponsoring Agency Code

15. Supplementary Notes

Compiled by Technical Library Branch and edited by Space Station Office, Langley Research Center, Hampton, Virginia.

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17. Key Words (Suggested by Authors(s))	18. Distribution Statement
Space Stations Space Platforms Space Technology Experiments Space Erectable Structures	Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price *
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